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Capelin in SA2 + Div. 3KL

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Table of Contents

Page

Abstract iii
Introduction iv
List of Participants xx

Chapter 1 Results of a Telephone Opinion Survey of Fixed Gear Capelin Licence Holders for 1998 - B. S. Nakashima and M. C. Clark 1-37

Chapter 2 The 1998 Inshore Capelin (Mallotus villosus) Fishery in NAFO Div. 3KL - B. S. Nakashima and B. W. Slaney 38-58

Chapter 3 Results of the 1998 Aerial Survey of Capelin (Mallotus villosus) Schools - B. S. Makashima 59-70

Chapter 4 Spawning and Early Development of Capelin (Mallotus villosus) from Bellevue Beach, Trinity Bay in 1998 - B. S. Nakashima and B. W. Slaney 71-82

Chapter 5 By-catches of capelin during spring and autumn bottom-trawl surveys in Divisions 2J3KL in 1998 - G. R. Lilly 83-111

Chapter 6 Absolute Abundance and Biomass of Juvenile and Adult Capelin (Mallotus villosus) in the Newfoundland Region (2J3KLNO) Estimated from the Pelagic Juvenile Fish Surveys, 1994-98 - J. T. Anderson, E. L. Dalley, and J. E. Carscadden 112-125

Page

Chapter 7 Year-class Strength of Northwest Atlantic Capelin (2J3KLNO) Estimated at the Larval Stage and Age One Based on the Pelagic Juvenile Fish Surveys, 1994-98 126-141
- J. T. Anderson, E. L. Dalley, and D. J. Davis

Chapter 8 Estimates of Consumption of Capelin 142-161
- J. Carscadden

Chapter 9 Predicting Mean Lengths of Female Capelin in SA2 + Div. 3KL 162-167
- J. Carscadden, G. T. Evans, and B. S. Nakashima

Chapter 10 Yearclass Strength of Capelin (*Mallotus villosus*) Using a Weighted Multiplicative Model 168-181
- B. S. Nakashima and G. Evans

Chapter 11 Seasonal changes in abundance, Distribution, and vertical migration of capelin in Placentia Bay 182-195
- R. L. O'Driscoll and G. A. Rose

Abstract

This document contains a number of discrete research results which were considered during the 1999 assessment of capelin in SA2 + Div. 3KL. These results are arranged in ten chapters. In addition, a meeting report, cross-referenced by chapter, is provided as well as a chapter pertaining to capelin in Div. 3Ps. The data for SA2 + Div. 3KL available included the results of studies on inshore capelin, 0-group and larval capelin, bycatches of capelin in groundfish surveys, capelin lengths, and consumption of capelin by predators. The analytical assessment of stock status used a multiplicative model.

Résumé

Le présent document renferme divers résultats de recherches distinctes examinés dans le cadre de l'évaluation de 1999 du capelan de la sous-zone 2 («SA2») et des divisions 3KL. Les résultats sont répartis en dix chapitres. On y trouve aussi un rapport des réunions, avec renvois aux chapitres, ainsi qu'un chapitre sur le capelan de la division 3Ps. Les données obtenues pour la «SA2» et les divisions 3KL portent notamment sur les résultats d'études sur le capelan côtier, les capelans larvaires et du groupe 0, les prises accessoires de capelan au cours des relevés du poisson de fond, la longueur des capelans et leur consommation par les prédateurs. L'évaluation analytique de l'état des stocks est faite par modèle multiplicatif.

Capelin in SA2 + Div. 3KL

1) Introduction

A capelin assessment committee met during March 1999 at NAFC, St. John's to assess the capelin stock in SA2 + Div. 3KL. A list of attendees is given in Appendix 1. Since 1994, capelin in SA2 and Div. 3KL have been assessed as one stock, based on evidence of movement of capelin in these areas.

2) Catch Trends

i) SA2 + Div. 3K

The capelin fishery in NAFO SA2 + Div. 3K was, until 1972, limited to inshore catches during the spawning season. In 1972, substantial catches were taken offshore by vessels from several countries. Catches peaked in 1976 at 212,000 t before declining in the late 1970's to 11,000 t in 1979.

Offshore catches during 1980-91 were restricted by quota and ranged between 500 and 57,000 t. The offshore fishery was generally conducted during August-November. The offshore fishery was closed beginning in 1992.

During the 1980's, an inshore directed roe fishery during June and July occurred, primarily in Div. 3L. Beginning in 1988, landings increased because of an increased share of the market for Canadian capelin with the closure of the Barents Sea capelin fishery. TACs generally reflected market demand and the increase of the TACs during the late 1980's can be attributed to the larger market share. These did, however, remain below the 10% of total spawning biomass that had been set as the biological criterion for setting the TAC.

During 1994 and 1995, a fishery was not prosecuted largely because female fish were too small to meet the size criterion in the management plan (sea run 50 count/kg). This size criterion was excluded from the management plan beginning in 1996 and a fishery proceeded when fish were marketable based on monitoring. Preliminary landings in SA2 +

Div. 3K during 1998, were 10,400 t compared to the quota of 11,400 t.

ii) Div. 3L

Catches in NAFO Div. 3L were less than 4,000 t prior to 1970, increased to a peak of 58,000 t in 1974, and declined to 12,000 t in 1979. During the 1980's an inshore roe fishery employing purse seines, capelin traps and beach seines occurred during June and July. This fishery has been later since 1991 due to the late arrival of capelin. In recent years, TACs have reflected market demand. In years when biological data were adequate to advise a specific TAC, the actual TACs have been less than advised on a biological basis.

The situation in Div. 3L regarding low landings in 1994 and 1995, the exclusion of the size criterion in the management plan beginning in 1996 and the monitoring programme were similar to that in Div. 3K. Preliminary landings in Div. 3L during 1998 were 20,300 t compared to a quota of 21,730 t.

Area	1992	1993	1994	1995	1996	1997	1998
SA2 + Div. 3K							
Inshore	17	11.4	11.5	11.5	9.7	11.4	11.4
TAC	18	13a	11.5	1a	8.9a	9.2	10.4a
Nominal catch			<.1a				
Div. 3L							
Inshore							
TAC	19.3	21	21	22	18.3	21.7	21.7
Nominal catch	3	23a	1a	1a	16.8	3.6a	20.3a
SA 2 + Div. 3KL							
Total nominal catch	21	36	1	1	25.7	12.8	30.7

a provisional

3) Information from Licensed Fixed Gear Fishers (Ch. 1)

During 1994-95, a questionnaire was designed to quantitatively evaluate biological and fishery-related information obtained from capelin fishermen. This survey was undertaken because of concerns about the utility of qualitative information coming from comments in some research logbooks or made directly to research personnel.

For the 1998 survey, the survey population size (n = 1829) was defined as all capelin fixed gear (traps and beach seines) fishermen licenced to fish capelin in NAFO Div. 3L and 3K in 1998. Employing a simple random sampling design and an expected response rate of 85% a sample population with 216 names was chosen to achieve a ±7% margin of error with 95% confidence intervals. Telephone interviews were completed between October 20 and November 30, 1998. The 185 completed questionnaires represented an 85% response rate, equivalent to the 85% expected.

Most respondents indicated that capelin abundance in their area was low with a mean response equal to 4.1. This is lower than 5.4 in 1996 and comparable to 3.8 in 1997. The abundance of capelin in 1997 was estimated to be 3.7 by respondents of this survey the same as the 3.4 estimated by the 1997 survey. Respondents clearly indicated that capelin abundance in 1998 was lower than when they first started to fish capelin. This response has been the same for all five surveys. Generally, most respondents considered capelin abundance to be low and similar to 1997.

According to the respondents, capelin occupied a small proportion of the spawning beaches in 1998. The number of respondents reporting no spawning was similar to 1997. The intensity of spawning was 4.7 (scale of 1, lowest, to 10, highest) compared to 4.1 in 1997 and 6.5 in 1996.

Spawning times were again delayed compared to the 1980's. The distribution of spawning times was later than in 1997.

The general size of females in 1998 was reported to be small 49%) or average (33%) with few reports of large females.

4) Inshore Data

i) Research Logbooks (Ch. 2)

The return rate of completed logbooks was higher than in 1997, 66% for fixed gear and 72% for mobile gear. The main reasons for discarding (live and dumped) capelin were variable but the ones mentioned most often were low percentages of females, small fish and redfeed. The overall discarding rate of 58% for traps was lower than in 1997 and the rate of 12% for purse seines was the lowest in the series. Excluding fish given away, 97% of trap and 88% of purse seine discards were released alive at sea. The remaining 12% of the purse seine discards which were dead were due to boat quotas.

Effort increased slightly over 1997 but overall it remained low. Trap fishing days and purse seiner searching time is low in the 1990's primarily due to monitoring initiatives put in place to reduce discarding of unmarketable capelin. The effect on fishing effort has been to concentrate the effort only when capelin are highly available and to reduce fishing time dramatically. This reduction has been especially evident in recent years. Consequently catch rate data are not comparable to data from the 1980's and are probably not indicative of stock abundance.

ii) Sampling

Commercial and monitoring samples were collected where possible. Since the catch rate data were not used in the multiplicative analysis, age compositions from these collections were not relevant to the quantitative analysis of stock status and were not presented.

iii) Aerial Survey (Ch. 3)

From 1990 to 1996, school areas had been estimated from digital imagery but beginning in 1997, a video camera was used. The switch to video technology was necessitated by budget reductions.

The total number of hours flown in 1998 was comparable to 1996 and less than in 1997. The less frequent coverage in 1998 can be attributed to poorer flying conditions, low amounts of capelin observed especially in Conception Bay, and fewer survey days. Compete coverage in Trinity Bay occurred eight times and six times in Conception Bay.

In Trinity Bay, the highest school area estimate was observed on July 13-14, similar to 1994-96. This time also corresponds to the peak period (July 11-21) of egg deposition on Bellevue Beach. In Conception Bay, the highest total school area (Trinity Bay and Conception Bay) was also observed on July 14. The total school surface area in 1997 was lower than the 1996 estimate and fourth highest in the series. The 1997 estimate was 554,095 m^2 (range 107,736 m^2 (1984) to 759,486 m^2 (1996)).

iv) Beach Survey (Ch. 4)

In 1990, spawning times, egg deposition and development, larval emergence and various environmental variables were monitored on two spawning beaches located at Arnold's Cove (Div. 3Ps) and Bellevue Beach (Div. 3L). The number of sites was expanded in 1991 to include five additional beaches in Div. 3KL. In 1995 only two beaches, Chapels Cove and Bellevue Beach were sampled and in 1996 and 1997, only Bellevue Beach was sampled.

Age compositions of spawning fish from 1990 to 1998 were dominated by age 3 fish in all years except 1992 when age 4's were most abundant. The 1998 spawning population consisted mainly of the 1995 yearclass (66%) followed by the 1994 yearclass (17%). The 1995 yearclass as age 2 represented 14% of the overall mature population spawning in the vicinity of Bellevue Beach.

One major spawning mode was observed in late July (July 21-31) with a few small modes on either side. Egg densities on Bellevue Beach were the highest in the series. This suggests for this area the mature population spawning on the beach sediment was considerably higher than in 1997.

The majority of pre-emergent larvae observed in beach sediments at Bellevue Beach in 1998 occurred July 31-August 4 and August 12-20. The density of pre-emergent larvae was the lowest in the series.

Emergent larval densities were very low in 1998 with one distinct peak on August 12 at night.

These results indicate that although there was a high density of eggs on Bellevue Beach, egg mortality was high. As a result, the production of pre-emergent and emergent larvae was low. These results imply that the 1998 yearclass is the weakest one produced at Bellevue Beach in the 1990's.

5) Offshore Data

i) Bycatch in Bottom Trawl Surveys in Div. 2J3KL (Ch. 5)

Capelin are frequently caught during bottom trawl surveys directed towards groundfish off southern Labrador and eastern Newfoundland. The distribution and magnitude of capelin catches from the surveys in Div. 2J and 3K during the autumns of 1978-94 have been compared with acoustic surveys for capelin to help evaluate acoustic survey coverage. As a result of these comparisons, acoustic surveys were expanded temporally and spatially during the late 1980's and 1990's.

Beginning in 1995, fall groundfish surveys have been conducted differently. The major difference was the adoption of a Campelen 1800 shrimp trawl as the sampling gear. Comparative fishing for capelin between the old and new gear was not conducted so the results starting in 1995 are not directly comparable to results from previous years. As a result trawl bycatch data after 1994 have not been incorporated into the multiplicative model.

The autumn distribution of capelin in Div. 2J and 3K changed in the early 1990's. In years prior to 1991 most of the capelin in Div. 2J3K were concentrated either in Div. 2J or in central Div. 3K, but after about 1991 most of the capelin caught during the bottom-trawl surveys or found in stomachs of cod caught during those surveys came from southeastern Div. 3K. In 1997 the distribution was still concentrated toward the southeast but with some indication of a return to the west.

The movement of capelin to more closely resemble historic distribution patterns continued in 1998. In general, the distribution of capelin was similar to the distribution in the 1980's, most notably 1986 and 1987.

In the spring surveys in Div. 3L, the Campelen trawl was not used until 1996. The extensive distribution and moderate to large catches of capelin in Div. 3L in the springs of 1996 and 1998 contrast markedly with the very small catches in 1991-95. Part of the increase may be attributed to the change of the Campelen trawl in 1996.

There is a notable contrast between the autumn surveys and the spring surveys with respect to the increase in trawlable biomass of capelin attending the change to the Campelen trawl. In the autumn series the biomass estimates in 1995-98 were about an order of magnitude greater than estimates in the mid-1980's. The extent of the increase in the spring series is less clear because of the very low estimate in 1997. However, the estimate in 1997 was of similar magnitude to several estimates in the 1970's and 1980's. This might indicate that the quantity of capelin in Div. 3L at the time of the survey in 1997 was substantially lower than the quantity present at the time of several of the surveys in the 1970's and 1980's.

ii) Catches of Pelagic 0- and 1-group Surveys (Ch. 6 & 7)

A research program to develop a multispecies, pre-recruit survey was carried out during 1991-93, as part of the Northern Cod Science Program. Beginning in 1994, a two-ship survey was initiated to measure pre-recruit abundances of cod and capelin throughout NAFO Div. 2J3KLNO, including both inshore and offshore areas. Large and small gear types were used to sample capelin in the upper water column, for the larval state (0-group; 3-50 mm), one year old (50-120 mm), and two year old capelin and older (2+, >120 mm). The intent of the survey was to sample pelagic juvenile cod, before they settle to the bottom and larval capelin, released from beach and bottom sediments.

The abundance data for larval (0-group) capelin were adjusted to account for different survey times in different years.

Bonavista Bay was not sampled in 1998 due to the early recall of the research vessel TELEOST. Bonavista Bay has been an important index area for capelin at both the larval stage and age one. The historical ratio for Bonavista Bay and other inshore bays was stable over years for larval capelin, so this ratio was used to account for the data lacking from Bonavista Bay. The yearclass strength estimate based on larval capelin increased from 1994 to a peak in 1996. The 1997 and 1998 yearclasses were weaker than 195 but greater than 1994. The mean length of larval capelin in 1998 was 11.7 mm, similar to means ranging from 8.9 to 10.7 mm during 1994-97.

For one-year-old capelin, the ratio between abundance in Bonavista Bay and other bays was high and as a result, a correction for the missing data from Bonavista Bay could not be made. As a result, the estimate of the 1997 yearclass for one-year-olds is underestimated. The patterns of yearclass abundance at age 1 are similar to the larval pattern, except for the 1997 yearclass at age 1 which, as noted, is biased down. The mean length of age one capelin in 1998 was 96.2 mm which is approximately in the middle of the range of mean lengths for the 1993-96 yearclasses.

Estimates of total abundance of capelin, age 1 and older, were calculated from the IYGPT catch data in these surveys. This was the first time that this approach has been attempted and the results were considered preliminary, pending further analysis and review.

6) Information on Capelin Predators (Ch. 8)

Estimates of consumption of capelin by predators are available, although many have not been updated for several years. Consumption estimates can vary depending on the assumptions underlying the calculations, however, they serve to illustrate sustenance provided to predators. Puffins were estimated to consume about 12,000 tons during the breeding season alone. Capelin consumption by seabirds was estimated at about 250,000 tons annually in the mid 1980's. Minke and fin whales were estimated to have consumed about 400,000 tons prior to their decline several decades ago. There are no new consumption estimates for whales. The most recent estimates for harp seals indicate about 700,000 tons of capelin were consumed in 1998 compared to about 350,000 tons in the early 1980's. Previous estimates for cod consumption indicated that during the early 1980's, cod in Div. 2J3KL were consuming 0.7 to 2.25 million tons of capelin annually. During the same time period, a minimum of 200,000 tons of capelin was estimated to have been consumed by Greenland halibut. Because the consumption estimates are calculated using predator biomass, they will vary with the marked changes in biomass of the various predators over time. Groundfish predators of capelin, such as cod, Greenland halibut and American plaice have declined in abundance from the early 1980's to the present. Harp seals have increased in abundance during that time. Based on the consumption estimates available, the increase in capelin consumption by harp seals is not as great as the decrease in consumption by groundfish predators.

There is considerable evidence that seabird ecology has changed in recent years. Differential breeding success of two species of seabirds in the Witless Bay area during the 1990's appeared to be related to the vertical availability of capelin. Kittiwakes, which are shallow divers, experienced relatively low breeding success during the early 1990's. Breeding success improved during 1996 and 1997 and approached historical levels.

The timing of kittiwake breeding was later in the 1990's, and like the delay in capelin spawning, appeared to be related to environmental factors. Puffins are a deeper-diving species and in contrast to kittiwakes, they have experienced good breeding success during the 1990's. Data on breeding success for these species were not available for 1998, however, it was noted that the weight of capelin in the diet of puffin chicks was lower in 1998, compared to 1997.

On Funk Island, gannet chick diets have shown a food change over two decades (1977-97) with capelin occurring in higher proportions in the 1990's. This shift to capelin is believed to be a result of greater availability of capelin during the chick feeding period, consistent with the later capelin spawning during the 1990's, and lower availability of warm-water species such as mackerel and squid. Data for 1998 were not available.

At the Gannet Islands, off the coast of Labrador, the weight of capelin in the diets of puffin chicks increased in 1997 and 1998, compared to 1996.

7) Other Studies

i) Predicting Mean Lengths (Ch. 9)

During recent assessments, positive relationships between mean lengths from fall offshore surveys and inshore the following year had been used to predict mean lengths of ripe females.

Because the size of females in 1997 had been incorrectly predicted from 1996 data, the evaluation of expected mean size of females in 1998 was modified. Two changes were made. First, data were grouped into two time periods, the 1980's and 1990's, because growth increments between fall and the following spawning season were different for these two time periods (specifically, growth in the 1980's was greater). Second, because it is not possible to predict whether growth will be more like the 1980's or the 1990's, the information was presented as two probability curves. These curves provided the probabilities of reaching mean lengths at spawning with a starting length measured in the fall under the two possible growth scenarios.

The mean length of maturing capelin in the fall of 1997 was 144 mm. The probability curves indicated that if growth was similar to the 1990's, there was about a 60% probability that the mean length of capelin in 1998 would be about 151 mm (average count of about 50). If however growth were more typical of the 1980's, there was a high probability that counts would be 50 or less.

Sampling data from the 1998 fishery indicated that the mean length of females was 147 mm indicating that the increment between the fall of 1997 and spawning season of 1998 more closely resembled the increments from the 1990's. This average is estimated from pooled data from the entire stock area and does not identify differences in mean lengths which might have been observed in the fishery.

The probability curves have been recalculated using the mean length of 139 mm of maturing female capelin from bycatch in the 1998 fall groundfish survey in Div. 2J3KL. These curves can be used to provide guidance on approximate counts in the mature female population in 1999 (counts are approximate because the weight-length relationship varies during the maturation process), depending on whether growth is more typical of the 1980's or 1990's. If growth is similar to that observed in the 1990's, there is virtually no chance that the average count will be less than 50 in 1999. If growth is similar to that of the 1980's, there is a 75% chance that the average counts will be less than 50. As noted previously, the analysis is based on pooled data from the stock area and consequently, it is not possible to account for differences that may occur between geographical areas and between spawning runs.

Biology and Resource Status

During the early 1990's, several biological changes, coincident with below normal water temperatures, have been documented. During offshore fall surveys in the 1980's, capelin were widely distributed from Div. 2J to Div. 3L, with a cline of larger to smaller capelin from north to south. In the early and mid-1990's, few capelin have been observed in Div. 2J and northern Div. 3K while most have been detected in southeastern Div. 3K and northern Div. 3L. The trends in size have been similar to the 1980's with larger capelin occurring in the northern part of the new distribution range and smaller capelin in the south. Also during the 1990's, capelin abundance measured by acoustic surveys was low.

Capelin distribution appears to be changing to more closely resemble the distribution observed in the 1980's. This was apparent in the distribution of capelin bycatch in the fall 1998 groundfish survey, continuing a trend that was first observed in fall 1997. In these years, capelin appeared more extensively in western Div. 3K and southern Div. 2J. Capelin bycatch in spring groundfish surveys in Div. 3L showed a broad distribution in 1996-98. This is similar to distributions observed in the mid- to late 1980's.

Surveys for young fish also detected 0-group capelin off the southern Labrador coast in 1998, the first appearance in the series (1994-98). In the same survey, ripe adult capelin and recently hatched larvae were detected in the Southeast Shoal area (Div. 3LNO); such occurrences had not been recorded in earlier surveys. These changes in capelin distribution are reminiscent of distributions observed during the 1980's, and are considered the first indicators that capelin may be exhibiting distributions and behaviour considered more typical than previously observed in the early 1990's. These changes are also coincident with a general warming of seawater in the Newfoundland region.

During the late 1980's and through the 1990's, capelin bycatches increased one hundred fold in groundfish surveys on the eastern Scotian Shelf (Div. 4VW). Capelin occur sporadically in this area and as a result, it is not known whether the increase was a result of immigration or enhanced reproductive success. Capelin also appeared on the Flemish Cap (Div. 3M) during the 1990's as bycatch in groundfish surveys and the shrimp fishery. Historically, capelin were rare here and this appearance was most likely due to migration. Increases in abundance in both areas, both historically and recently, have coincided with cold water. There are no new data for Flemish Cap but preliminary results from the eastern Scotian Shelf indicate that March 1999 bycatch levels remain high.

The average size of capelin declined during the 1990's and has remained small. The timing of inshore spawning was delayed during the 1990's and this trend has also continued. The later spawning has been correlated with colder water and smaller fish size. Although there is a general warming trend in sea temperature, fish size remained small in 1998 and it may be that spawning will continue to be later unless sizes return to normal.

Other observations of unusual characteristics of capelin biology during the 1990's, not documented in the scientific literature, include: an increase in the relative proportion of spawning at night; changes in physical structure of the otoliths causing problems in age determinations; an increased incidence of females with ovaries full of unspawned eggs in the fall; a consistent and relatively high proportion of spent females in the fall since 1992.

In general, it appears that some characteristics of capelin such as offshore distributions are changing to more closely resemble patterns observed in the 1980's. Although the observations are at this stage qualitative, the dramatic shifts in the early 1990's appeared to be linked with below normal seawater temperatures whereas the reversal of this pattern now seems to be occurring with a warming trend.

Evaluation of Resource Status (Ch. 10)

In the past evaluations of resource status, seven partially overlapping series of indicators were combined in a mathematical model to provide relative estimates of yearclass strength. The indicators and their years of existence are:

1) aerial survey index 1982-98
2) purse seine catch rate index 1981-96
3) trap catch rate index 1981-93
4) groundfish 3L fall bycatch 1985-94
5) groundfish 2J3K fall bycatch 1985-94
6) Russian 2J3K fall commercial catch rate index 1972-91
7) egg deposition index 1990-98

The 1998 aerial survey index was lower than 1997 and below the 1990-98 average. The egg deposition rate was the highest in the series (1990-98). Catch rate data from purse seines and traps in 1997 and 1998 are not considered comparable to catch rate from the 1980's because of low effort levels, in part due to quality monitoring. As a result, catch rate data for these years were not used in the model. A change in the gear in the fall groundfish survey in Div. 2J3KL in 1995 has effectively produced a new series which will be examined in more detail in the future for possible inclusion in the model.

A second mathematical model was also incorporated into past assessments. This model produced a recruitment index using results from surveys for larvae and one-year-olds. The indicators used in this model and their years of availability are:

1) 0-group index 1994-98
2) sediment larval index 1990-98
3) emergent larval index 1990-98
4) Conception Bay sediment larval abundance 1987-93
5) oceanic age 1 index 1994-98

The trends in relative yearclass strength between the two indices were similar and as a result, the 12 indicators were combined into one model in this assessment. Combining the data provides more information for the evaluation of yearclasses that are expected to contribute to the spawning stock in 1999. It also contains the information on the youngest yearclasses (1997 and 1998) which was previously contained in the recruitment model alone.

The method of combining the indices in the model was also refined in this assessment. In previous assessments, individual indicators were given equal weight in the process of combining them. In the current assessments, importance of inclusion of each indicator was determined by the amount of uncertainty in its contribution to the overall index. Indicators with high uncertainty contributed less to the final index.

According to these results, the 1990's might be characterized as a period of relatively strong yearclasses compared to the 1980's. However, the standard errors are so large in recent years that the relative abundances of many of the yearclasses are statistically indistinguishable.

In previous years, an additional mathematical model (which included an assumption that recruitment does not change) provided trends in mature biomass. This model was not updated. It is clear that one of the major assumptions, that is, constant yearclass strength, is violated. Furthermore, standard errors were so large that trends in mature biomass over the time series (1980-present) could not be identified.

Sources of Uncertainty

Many sources of uncertainty cited previously remain. These included the large-scale changes in distribution, the unreconciled divergence between low offshore acoustic estimates and inshore indices in the 1990's, difficulties in ageing capelin in the 1990's compared to earlier years and the large statistical uncertainties from the mathematical model. The mathematical models used assume that a number of things are constant over time; for example, maturity schedules and survival rates. The effects of violations of these assumptions have not been examined.

While the use of the method to determine the relative contribution of indicators in the formulation of the model is considered an improvement, there remains particular concerns about the indices themselves and whether they are now providing reliable indicators of stock status.

During the 1980's, catch rates and other indices showed similar annual patterns. However, catch rates may now be poor indicators of stock status. Fishing effort has declined in recent years, due in part to monitoring for quality and fishing only when the fish meet market requirements. This results in catch rates which probably cannot be compared to the 1980's and may not reflect stock status. Both the aerial survey and egg deposition studies which provide fishery-independent indices, have been reduced in geographical coverage and/or intensity. The aerial survey now covers only the transects in the inner parts of Trinity and Conception Bays. The only beach study area is Bellevue Beach compared to six study beaches (three in each of Div. 3L and 3K) in the original study. There are two major concerns with the 1997 and 1998 aerial and beach surveys: 1) they are so limited in geographical coverage compared to the overall stock area that the results may not reflect status of the whole stock, and 2) there were indications from the 1997 opinion survey that abundance may be changing at different rates within the stock area, for example, within the bays versus near headlands. If this is the case, the limited geographical coverage by the aerial and beach survey may not detect these changes. While the offshore surveys for early life stages (primarily 0- and 1-group) are continuing, acoustic surveys for older juveniles and adults have been discontinued. While it appears that the acoustic survey may be re-instated, there is likely to be a period of a few years before estimates of abundance will be available. The concern that scientific investigations have been reduced to such an extent that it may not be possible to assess the status of capelin stocks, expressed in last year's report has not diminished.

There is also concern over the divergence between the assessment using the mathematical model and the opinions of fixed gear fishermen, particularly the contradiction in comparisons between the 1990's and earlier periods. A longer timeseries and further evaluation are necessary to determine whether the opinion survey can be used as a stock status indicator but this evaluation will be very difficult without other sources of data, which as noted, may be compromised by reduced coverage.

Outlook for 1999

The 1995 and 1996 yearclasses are expected to be major contributors to the 1999 spawning stock. The analyses presented here indicate that these yearclasses are relatively abundant compared to other yearclasses. Even if average fish size is small in 1999, the presence of two relatively strong yearclasses would be expected to result in a spawning biomass in 1999 that is above average when compared to biomasses in the 1990's.

The results from the mathematical model suggest that both the 1997 and 1998 yearclasses are weaker than the 1995 and 1996 yearclasses. The 1998 yearclass appears to be as weak as the 1991 yearclass, the weakest yearclass in the 1990's. If the relative strengths of these yearclasses do not change with additional data, then the capelin stock will probably decline in the future.

There have been many problems and uncertainties in assessing the capelin stocks in recent years in part perhaps to changing behaviour during unusual oceanographic conditions, as well as reduced directed scientific research. It is unlikely that future assessments will be improved at the current level of research activity.

Results of Capelin Studies from Other Areas (Ch. 11)

Although not directly relevant to the assessment of the capelin stock in SA2 + Div. 3KL, data were presented on capelin in Placentia Bay (Div. 3Ps) and these results are included.

The abundance and distribution of capelin (Mallotus villosus) in Placentia Bay, southeastern Newfoundland, were assessed during four acoustic surveys in January, March, and June 1998, and in January 1999. Most capelin observed were immature (75% < 130 mm). Capelin biomass was highest in June 1998, with an acoustic estimate of 132,000 t for outer Placentia Bay. Capelin biomass in the outer Bay was much lower in January 1998 (13,000 t), March 1998 (2,100 t), and January 1999 (390 t), suggesting seasonal changes in spatial distribution. There were also seasonal differences in vertical distribution of capelin. In June capelin were close to the surface at night and near the bottom during the day. At other times no diurnal vertical migration was evident.

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Results of a Telephone Opinion Survey of Fixed Gear Capelin Licence Holders for 1998

by

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Introduction

A questionnaire was used to quantitatively evaluate biological and fishery-related information obtained from capelin (Mallotus villosus) fishers in 1998. The questions were developed to supplement information collected by the research logbook and beach sampling programmes and to quantify to some extent the impressions of fishers on the status of the capelin stock in Div. 3KL. All questions were the same as in the 1997 survey.

Methods

The survey population size of 1829 (3L: 803, 3K: 1026) was defined as all capelin fixed gear (traps and beach seines) fishers licensed to fish capelin in NAFO Div. 3L and 3K in 1998. A list of names and telephone numbers was provided by the Resource Management Division, Fisheries and Habitat Management Branch, DFO. Employing a simple random sampling design and an expected response rate of 85% a sample population with 216 names was chosen to achieve a ±7% margin of error with 95% confidence intervals (Gower and Kelly 1993). The sampling statistics do not apply to the comments presented in Table 4 nor the geographical comparisons in Figure 14 and Tables 1-3. The survey was conducted by telephone interview.

Telephone interviews commenced October 20, 1998 and were completed on November 30, 1998. Interviewers were unable to contact 31 individuals on the licensing list who were in the random sample population. Of these 10 could not be contacted despite five attempts to do so, 9 had no telephone in service (disconnected, wrong number, no telephone number), 1 was out of the province during the survey, 2 declined to participate, 7 did not fish, and 2 persons were deceased. The 185 completed questionnaires represent an 85% response rate equivalent to the expected.

Results and Discussion

Abundance Questions

Three questions (Appendix A) comparing abundance of capelin in 1998 to previous years were asked in the survey. Most respondents indicated that capelin abundance in 1998 in their area was low (Fig. 2) with a mean response equal to 4.1. This is lower than 5.4 in 1996 and comparable to the 3.8 average for last year. The abundance of capelin in 1997 was estimated to be 3.7 by respondents of this survey, the same as the 3.8 estimated by the 1997 survey (Fig. 3). In all fishing areas except for the Southern Shore the average abundance of capelin in 1998 was similar to or slightly higher than estimated in 1997 (Table 1). In general those areas with a 'better' fishery tended to have higher abundance. When given three options in question 3 (Appendix A) respondents clearly indicated that capelin abundance in 1998 was lower than when they first started to fish capelin (Fig. 4). This response has held firm for all five surveys. Generally most respondents considered capelin abundance to be low and similar to 1997.

Spawning Questions

Questions 4-13 (Appendix A) relate to spawning. According to respondents capelin in 1998 occupied a small proportion of the available spawning beaches (Fig. 5). The number of respondents reporting 'no spawning' was similar to the response in 1997. The responses in the 1-5 beaches category is lower than in 1997 (Nakashima 1998), however most responses were at the low end of the range. Capelin spawned on more or the same number of beaches in 1998 compared to 1997 (Fig. 6). The intensity of spawning in 1998 (Fig. 7) was similar to 1997 with a mean spawning intensity of 4.7 compared to 4.1 in 1997. Spawning intensity in 1998 was similar among geographic areas (Table 2). Spawning intensity in 1998 was generally higher or the same compared to 1997 (Fig. 8). Approximately 40% of respondents were unable to make a comparison. Egg densities at Bellevue Beach in 1998 were almost twice as much as in 1997 (Nakashima and Slaney 1999b) while the total school area estimated by the aerial survey in 1998 was lower than the 1997 estimate (Nakashima 1999). Respondents felt spawning on beaches in 1998 was more intense than in 1997.

Capelin spawned off beaches more often in 1998 than in 1997 (Fig. 9). Non-responses remain high at almost 30%. The historical view of capelin spawning off beaches is similar among the three most recent surveys (Fig. 10). The 111 persons who responded in the affirmative to question 8 were asked to give reasons why capelin may have spawned in deeper water in 1998 (Appendix A: question 9). The most frequent response was warmer water temperatures in deeper water (45%). Other possibilities suggested were the presence of predators (e.g. humans, seagulls) driving capelin away from beaches (15%), dirty water (4%), low capelin abundance (3%), and no cod to drive capelin ashore (2%). Approximately 8% said capelin in their area always spawned in deep water which has remained consistent for all years surveyed. The remaining 21% gave no response.

The time when spawning began in 1998 was delayed compared to the 1980s. The distribution of times was later than in 1997. This is the first time since the survey began in 1994 that first spawning times were reported for September. Of those answering question 11a who recalled when spawning began in 1998 the majority suggested late June to late July with most respondents favouring early July to early August (Fig. 11). Spawning was later than in 1996 or 1997. Almost 8% observed no spawning in 1998, much less than the 28% in 1997. Comparing the start of the spawning season in 1998 to 1997 in question 11b most respondents who expressed an opinion indicated that it was the same or later (Fig. 12). Compared to when fishers first started fishing capelin, there has been an overwhelming majority who felt that spawning times in 1994-98 have been later (Fig. 13). Spawning began in early July at Bellevue Beach, Trinity Bay in 1998 (Nakashima and Slaney 1999b) but the majority of the spawning took place in late July.

The size of females was small (49%) or average (33%) with very few reports of large females (1%) (Fig. 14). These observations are consistent with the low mean lengths observed in samples collected in 1998 (Carscadden 1999; Nakashima and Slaney 1999b).

Questions on the Fishery

Almost all licensed respondents (94%) intended to fish capelin in 1998 and 60% of them set out fishing gear or searched for capelin. Of the 104 respondents who fished in 1998, 45 used one trap, 36 used two traps, 3 fished more than 2 traps, 13 used trap(s) and a beach seine, and 20 used a beach seine. Only 18% who fished had no landings in 1998 (Fig. 15) and average reported landings were 68,500 lbs (31,100 kg). The majority reported discards of less than 25,000 lbs (11,340 kg) (Fig. 16). Combining estimates of landings and discards the average catch per telephone respondent in 1998 was 118,100 lbs (53,600 kg) (Fig. 17) which compares favourably with the average catch from research logbook estimates (48,100 kg, Nakashima and Slaney 1999a). Table 3 compares the average catch per fisher reported in the opinion survey and the research logbook program by fishing area. Most comparisons are similar with the opinion survey always having the higher catch rate. The research logbook catch rates are considerably lower for Notre Dame Bay and the Southern Shore where landings and logbook returns were low. Also, the research logbook data were only for capelin traps. Most of the discarded capelin were released alive (Fig. 18), comparable to what was reported in research logbooks. The reasons for discarding were low percentage of females (34%), redfeed (19%), small fish (16%), capelin mixed with cod (9%), spent fish (5%), problems with buyers and selling capelin (5%), catch too small amount to land (3%), capelin mixed with other species (3%), and capelin caught after the season was closed (2%). Research logbook results suggest small females, the presence of redfeed, and low percentage of females as the major reasons capelin were discarded from traps (Nakashima and Slaney 1999a). Discarding in 1998 was reported to be lower than in previous years (Fig. 19). In contrast trap research logbooks report one of the highest discarding rates in recent years (Nakashima and Slaney 1999a). The same situation arose in 1997 (Nakashima and Clark 1998). Of those who fished, 57% reported bycatches of a few pounds to several thousand pounds. The most frequent bycatch species based on estimated weight were cod (60%), herring (11%), and small cod (9%). Squid, flatfish, and rock cod were also mentioned. Of these 79% were released alive.

Questions on Climate and Ocean Conditions

The sample population was asked question 24 (Appendix A) pertaining to general weather and oceanic conditions during the summer of 1998. Wind conditions in the summer of 1998 were considered calm by 4% of the population, light or favourable by 62%, moderate by 26%, and windy by 9%. Air temperatures were reported to be cool (3%), average (10 %), warm (68%), or hot (19%). The summer was mainly sunny (75%) or half sunny and half overcast (22%). Ice was not a concern in 1998 with only 2% reporting moderate or heavy ice. Fifty-four percent reported icebergs in their area. Water temperatures were generally warm (62%) or average (27%). Reports of cold (3%) or cool (7%) water temperatures were rare. Overall weather conditions were considered to be good (54%) to excellent (26%) for fishing throughout the region.

Comments by Respondents

At the end of the telephone interview each of the 185 respondents were provided the opportunity to make comments. The range of topics covered most aspects of capelin biology and the fishery and also on other fisheries. The comments relative to capelin have been summarized in Table 1. In many instances more than one comment was given but only one comment per respondent was reported in Table 1.

Demographics of the Sample Population

All respondents were asked questions 25-28 to characterize the sample population of fixed gear fishers and to be able to relate in subsequent analyses responses to areas fished and experience in the fishery. The distribution of responses to question 25 shows the number of years of involvement in the capelin fishery (Fig. 20). Fishing vessel lengths varied from 17 to 55 feet with 83% less than 36 feet (Fig. 21). Estimated vessel capacity for capelin was less than 30,000 lbs (13,600 kg) for 80% of the fishing fleet involved in the fixed gear capelin fishery (Fig. 22). Most licensed fixed gear capelin fishers are between 35 to 55 years of age (Fig. 23). The average age was 46 years. Average vessel capacity (20000 lbs or 9,100 kg) and vessel length (30 ft) of the fleet and the age structure of the licence-holders (Fig. 23) are comparable to previous surveys. The highest proportion of respondents was from Notre Dame Bay with the fewest fishers in the sample population from Bonavista Bay and St. Mary's Bay (Fig. 24). The distribution of responses from Div. 3KL in the sample population is similar to other years except for the small number from Bonavista Bay.

Summary

Results from the telephone survey of fixed gear capelin fishermen provided observations on beach spawning, local capelin abundance, fishing activities, and summer weather conditions. In 1998 most respondents indicated that capelin spawned later, spawned on fewer beaches than in the past, and spawned subtidally away from beaches more so than in the 1980s. Spawning intensity was 4.7. Most licensed fishers intended to fish in 1998 and 60% of them actually put their gear in the water or searched for capelin. Commercial fixed gear fishing occurred in all areas of Div. 3KL. The weather was generally considered favourable for fishing and water temperatures were considered warmer than normal. Overall respondents felt capelin abundance and spawning on beaches in 1998 was slightly more than observed in 1997 but continues to be lower than in the 1980s. The results of this survey as applied to Div. 3KL represent the opinions of the survey population at the time the survey was conducted with a ±7% margin of error 19 times out of 20.

Acknowledgements

Morris Clark and Barry Slaney conducted the telephone interviews. Our appreciation to the individuals who took the time to share their knowledge with us. M.Y. Farrell assisted in the preparation of the manuscript.

References

Carscadden, J. 1999. Atl. Fish. Res. Doc. 99/ .

Gower, A., and K. Kelly. MS 1993. How big should the sample be? Social Survey Methods Division, Statistics Canada. 14p. (Mimeo).

Nakashima, B. S. 1996. Results of a telephone survey of 1995 fixed gear capelin licence holders. pp. 4-26. In: Anon. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 96/90.

1997. Results of a telephone survey of 1996 fixed gear capelin licence holders. pp. 28-41. *In*: Anon. Capelin in SA2 + Div. 3KL. CSAS Atl. Fish. Res. 97/29.

1998. Results of the 1997 aerial survey of capelin (*Mallotus villosus*) schools. pp. 50-61. *In*: Anon. Capelin in SA2 + Div. 3KL. CSAS Atl. Fish. Res. Doc. 98/63.

Nakashima, B. S. and M. C. Clark. 1998. Results of a telephone survey of 1997 fixed gear capelin licence holders. pp. 23-37. *In*: Anon. Capelin in SA2 + Div. KL. CSAS Atl. Fish. Res. Doc. 98/63.

Nakashima, B. S., and B. W. Slaney. 1999a. The 1998 inshore capelin (*Mallotus villosus*) fishery in NAFO Div. 3KL. pp. . *In*: Anon. Capelin in SA2 + Div. KL. CSAS Atl. Fish. Res. Doc. 99/.

Nakashima, B. S. and B. W. Slaney. 1999b. Spawning, egg densities, and pre-emergent larvae from Bellevue Beach, Trinity Bay in 1998. pp. . *In*: Anon. Capelin in SA2 + Div. 3KL. CSAS Res. Doc. 99/.

Table 1. Average capelin abundance in 1997 and in 1998 by fishing area. The number of responses is given (N).

Area	N	Abundance	
		1998	1997
White Bay	42	5.6	4.8
Notre Dame Bay	69	3.2	3.0
Bonavista Bay	4	3.3	3.0
Trinity ay	21	4.1	3.5
Conception bay	28	4.5	3.8
Southern Shore	15	3.7	4.1
St. Mary's Bay	5	5.2	5.0

Table 2. Average spawning intensity in 1998 by geographical area. The number of responses is given (N).

Area	N	1998 Spawning intensity
White Bay	42	4.5
Notre Dame Bay	70	4.7
Bonavista Bay	4	5.0
Trinity ay	21	4.8
Conception bay	26	5.0
Southern Shore	15	4.3
St. Mary's Bay	5	4.0

Table 3. Catch rates (catch (t) per fisher) by fishing area estimated from the opinion survey and research logbooks. Sample sizes are given (N).

Fishing area	Opinion		Logbook	
	N	Catch rate	N	Catch rate
White Bay	42	48.5	13	34.6
Notre Dame Bay	70	43.3	2	4.0
Bonavista Bay	4	21.0	4	16.7
Trinity Bay	21	66.1	17	64.4
Conception Bay	28	74.9	12	64.5
Southern Shore	15	41.9	1	19.1
St. Mary's Bay	5	33.3	2	22.9

Table 4. Summary of comments pertinent to capelin or the capelin fishery.

Comment	Number of responses	% response
No capelin/scarce	26	14.1
Lots outside and after quota closed	2	1.1
Most capelin and biggest after quota closed	4	2.2
Not much and small	2	1.1
Good size and abundant	1	0.5
Fair amount/abundant and small	5	2.7
Small	1	0.5
Bay stocks of large capelin gone, small offshore ones left	1	0.5
Capelin only in a few spots	1	0.5
Capelin around long time	2	1.1
Capelin deep not come to land	22	11.9
Later coming in every year	3	1.6
Spawning on unusual beaches	1	0.5
Spawning night time only	1	0.5
Spawning in fall (Sept.)	3	1.6
Spawning later; all sizes mixed	1	0.5
Caught/destroyed by seiners/longliners	11	5.9
Capelin are overfished	1	0.5
Fishery should be closed	25	13.5
Cod closed; capelin should be closed	5	2.7
Should not be destroyed for nothing/low price	7	3.8
Low abundance, close fishery	5	2.7
Leave along for a while	3	1.6
Need better monitoring	4	2.2
IQ system	9	4.9
Need bigger quota	2	1.1
Opened too early	6	3.2
Opened too late	4	2.2
Buyers not interested in buying	4	2.2
No comments	23	12.4

Appendix A

SURVEY QUESTIONNAIRE OF FIXED GEAR CAPELIN Licence HOLDERS

Questions on Abundance:

1. Using a scale of 1 to 10 with 1 being the lowest and 10 the highest how abundant (i.e. numbers of fish) were capelin in your area this year?

2. Using a scale of 1 to 10 with 1 being the lowest and 10 the highest how abundant (i.e. numbers of fish) were capelin in your area last year?

3. How would you describe the abundance of capelin this year compared to when you first started fishing capelin?

Questions on Spawning:

4. Approximately on how many beaches in your area do capelin usually spawn?

5. Approximately on how many beaches did capelin spawn this year?

   If 'none' or 'don't know' go to Ques. 8

6. How many beaches did capelin spawn on this year compared to last year?

7a. On a scale of 1 to 10 with 1 being low and 10 being high how intense was capelin spawning in your area this year?

7b. What was the intensity of capelin spawning this year compared to last year?

8. Did capelin spawn off beaches in your area in deeper water?

   If yes go to Ques. 9
   If 'no' or 'don't know' go to Ques. 10
   If no spawning on beaches or in deep water go to Ques. 14

9. Why do you think capelin spawned in deeper water this year?

10. How often since you started fishing have you observed capelin spawning off beaches in deeper water?

11a. When did capelin first spawn in your area this year?

11b. Did spawning start at the same time this year as last year?

12. What was the overall size of female capelin this year?

13. How does the timing of capelin spawning (beginning and end) this year compare to when you first started fishing capelin?

Questions on the Fishery.

14. Did you intend to fish for capelin this year?

If 'yes' continue, if 'no' go to Ques. 24

14b. Did you set your fishing gear or go out and search for capelin this year?

If 'yes' continue, if 'no' go to Ques. 24

15a. What type of fishing gear did you use?

If a 'trap' go to Ques. 15b if other gear types go to Ques. 15d

15b. How many traps did you fish?

15c. How much capelin does your trap(s) hold when full?

15d. Did you always fish this gear type or have you fished other types in the past?

If fished other gear types what were they?

16. Approximately how much capelin did you and your crew land this year?

17. Approximately how much capelin (live or dead) did you and your crew discard (i.e. did not land or sell)?

    If discarding >0 continue, if discarding is '0' go to Ques. 21

18. What percent of the discarded capelin do you think survived?

19. Why were capelin discarded? Please give reasons in order of importance.

20. How does the amount discarded this year compare to all the other years you've fished capelin?

21. While fishing capelin did you and your crew catch any other species (i.e. by catch)?

    If 'yes' continue, if 'no' go to Ques. 24

22. What species (three maximum) were they and approximately how many (weight) of each?

23. What was the condition of the by catch when released?

Questions on Climate/Ocean Conditions:

24. Weather plays an important role in the biology of capelin. Please describe the local weather and sea conditions in your area during capelin spawning season (usually June/July).

    Winds-force and direction, air temperature, sun or overcast, ice, water temperature

General Information:

25. In what year did you first start fishing capelin commercially?

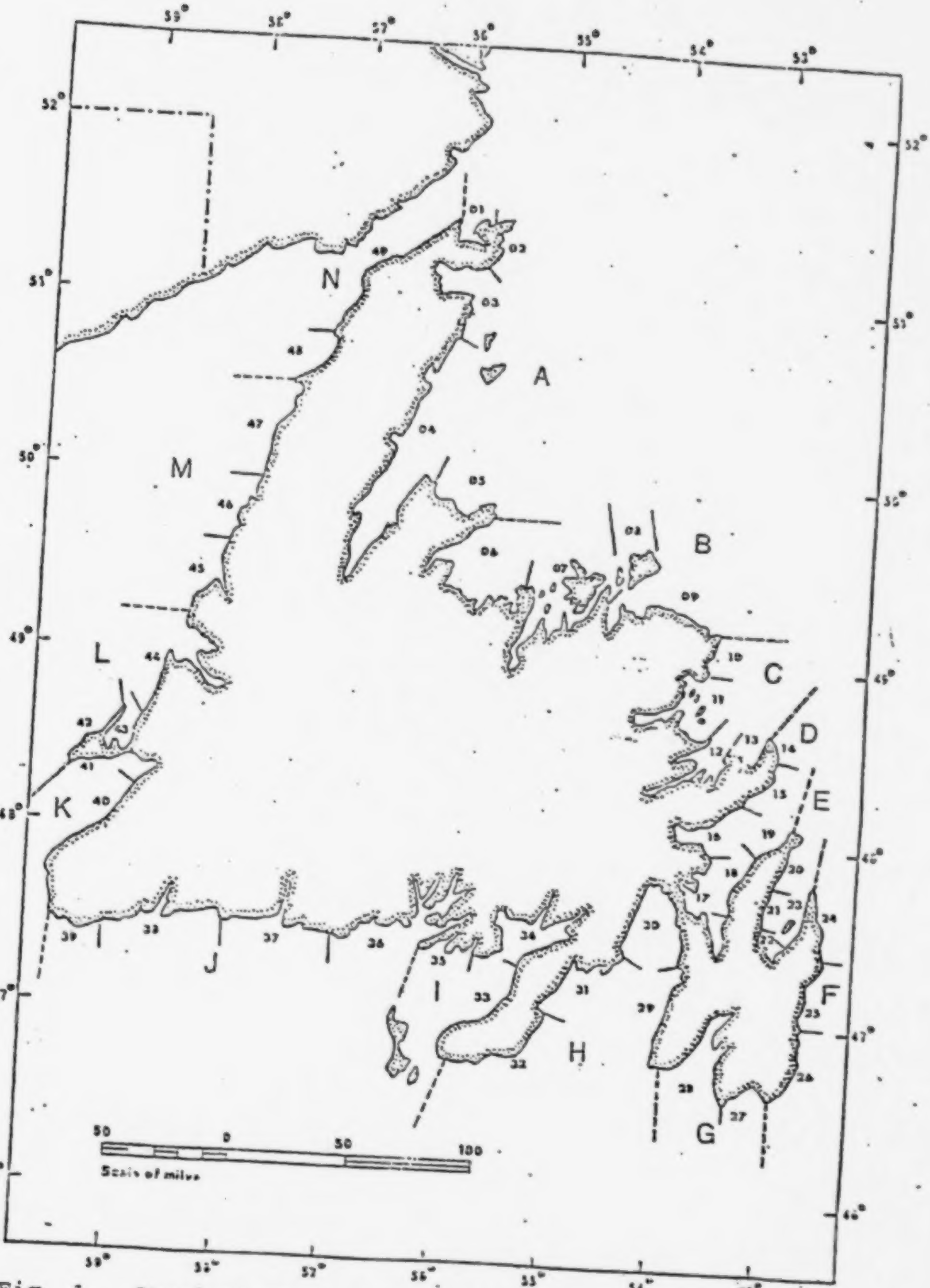
26. What is the length and capacity (maximum weight of capelin it can carry) of your vessel?

27a. Have you always fished for capelin in the same location?

If 'no' continue, if 'yes' go to Ques. 28

27b. Where else have you fished for capelin?

28. How old are you?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50
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Scale of miles

Fig. 1. Statistical areas (A = White Bay, B = Notre Dame Bay, C = Bonavista Bay, D = Trinity Bay, E = Conception Bay, F = Southern Shore, and G = St. Mary's Bay) for the Newfoundland Region.

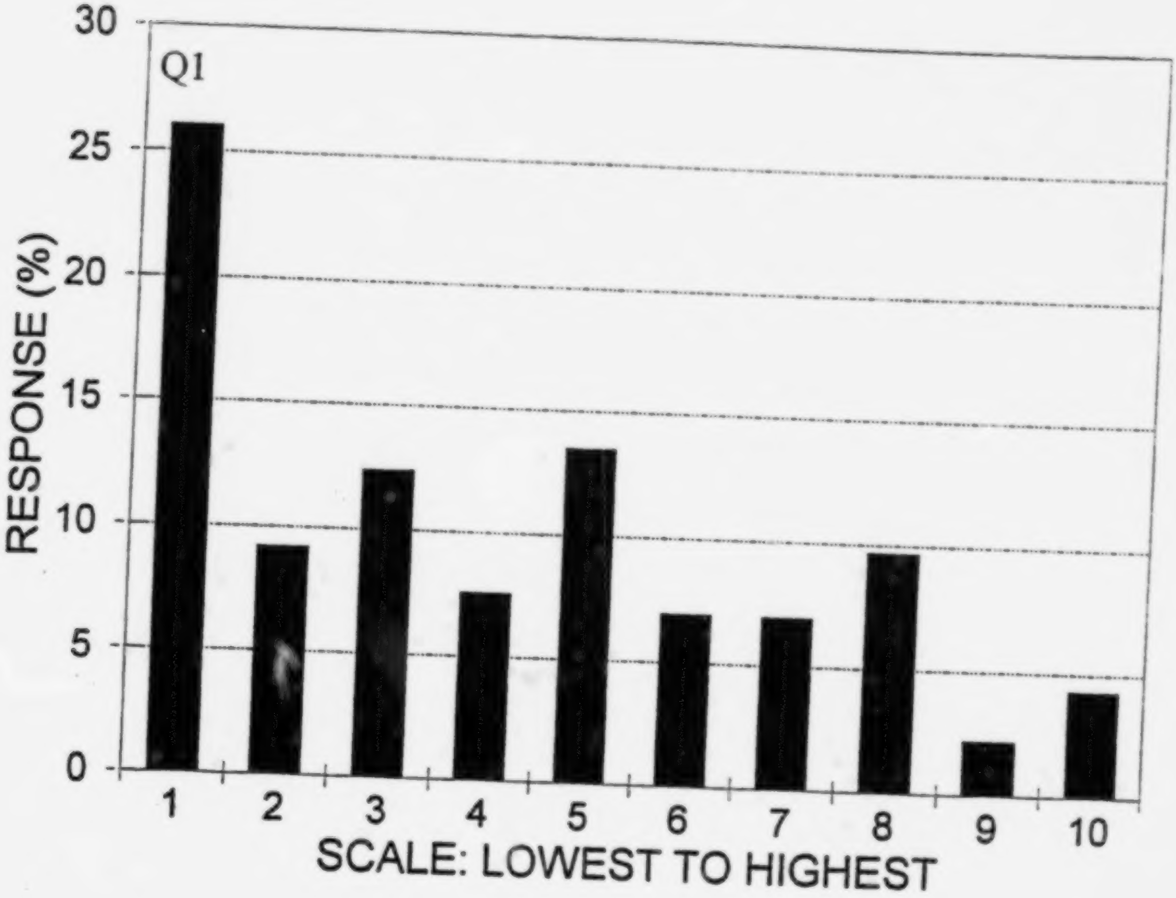

Fig. 2. Response to question 1 on the abundance of capelin in 1998.

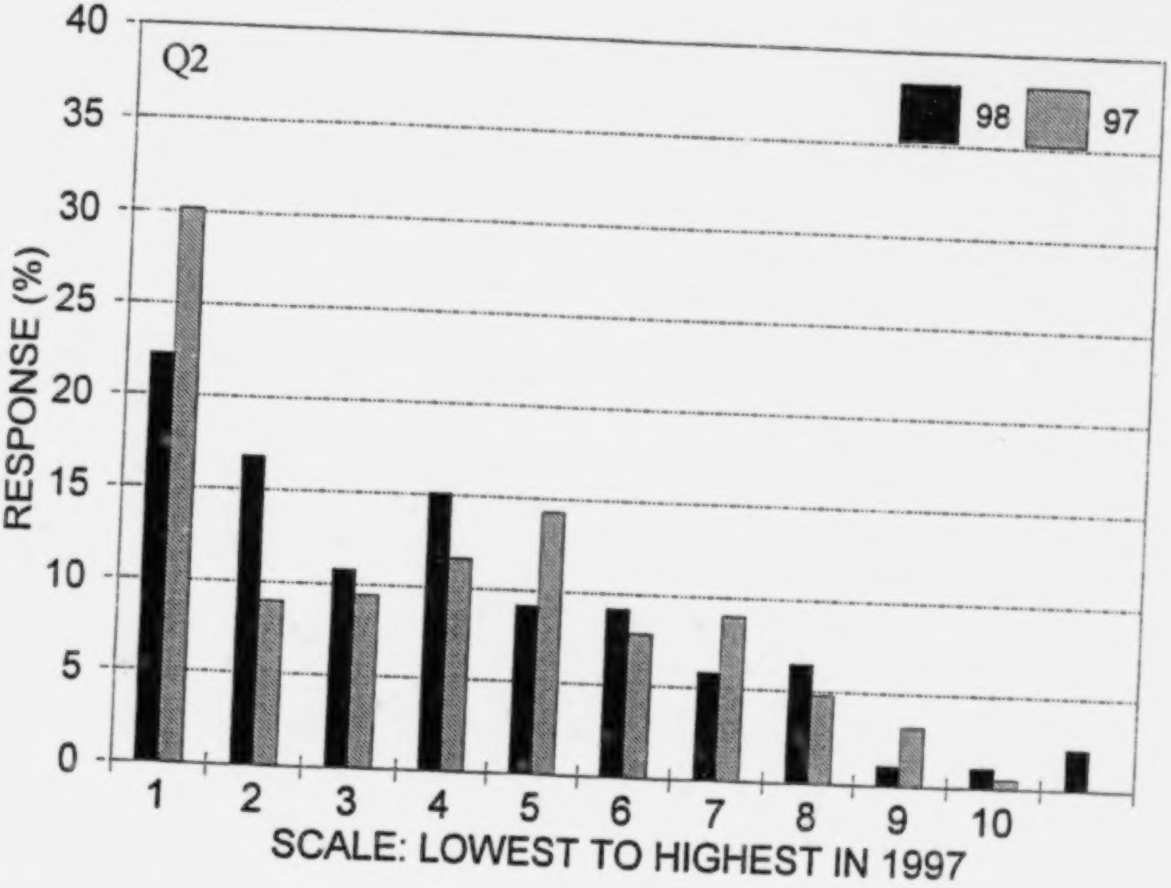

Fig. 3. Impression of capelin abundance in 1997 from the 1997 (Nakashima and Clark 1998) and 1998 surveys.

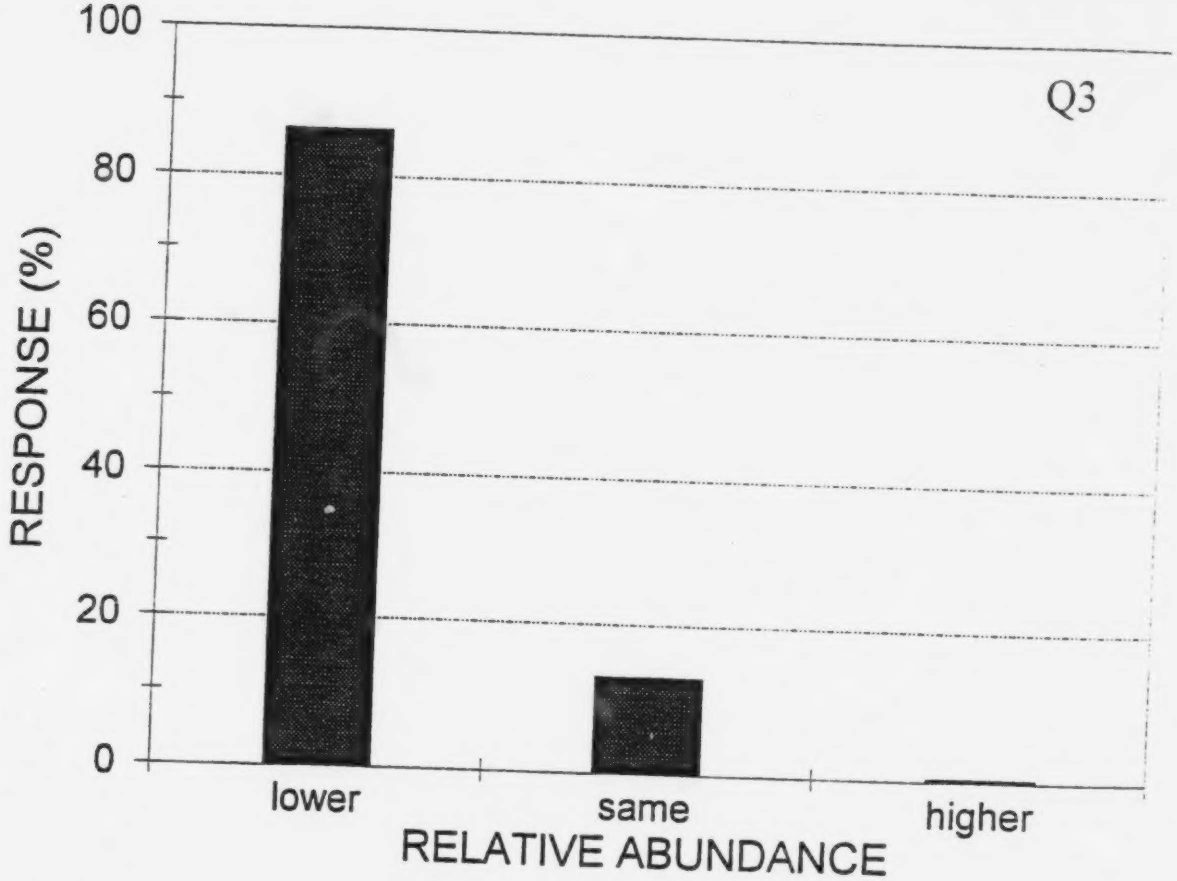

Fig. 4. Response to question 3 concerning abundance in 1998 compared to first started fishing. No answer given (na).

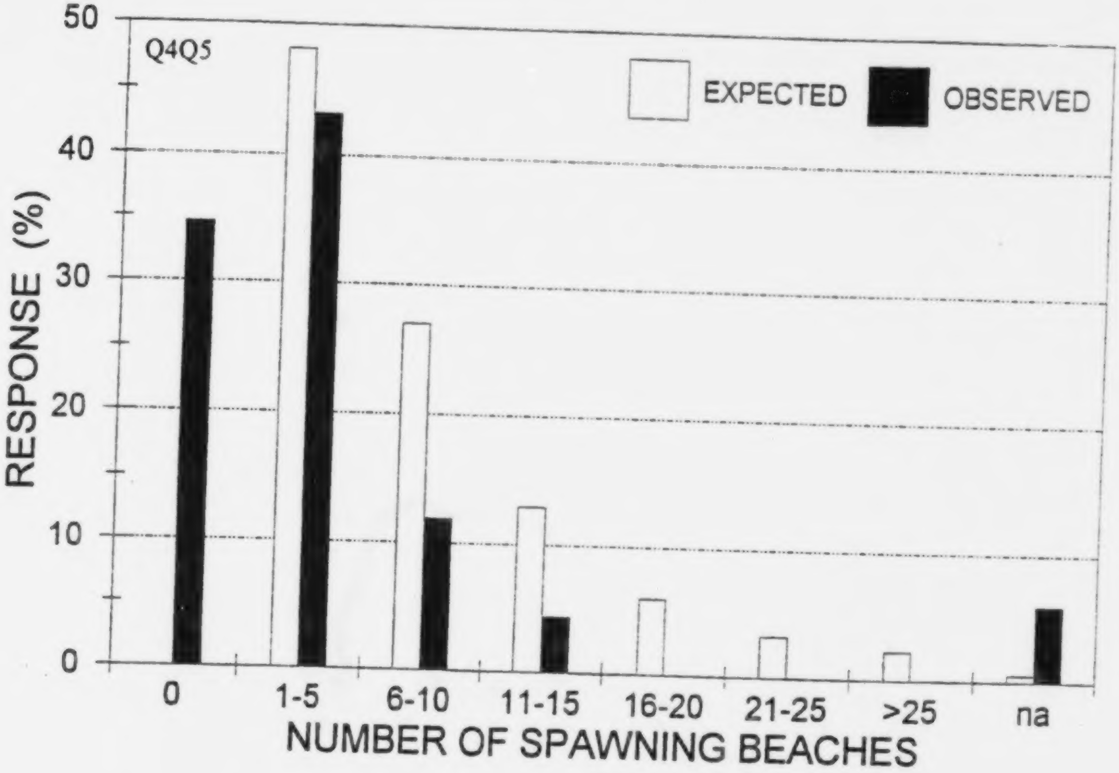

Fig. 5. Comparison of the number of beaches capelin spawned on in 1998 to the available beaches. No answer given (na).

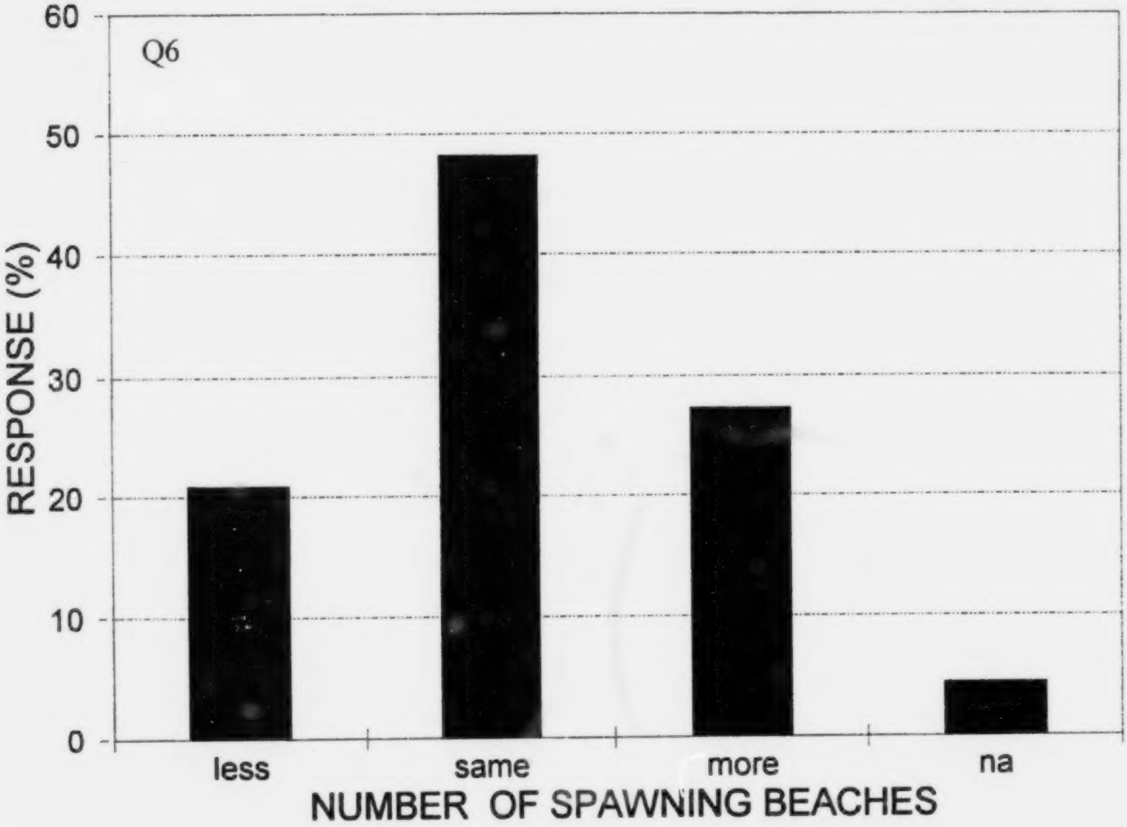

Fig. 6. Response to question 6 concerning the relative number of spawning beaches occupied in 1998 compared to 1997. No answer given (na).

Fig. 6

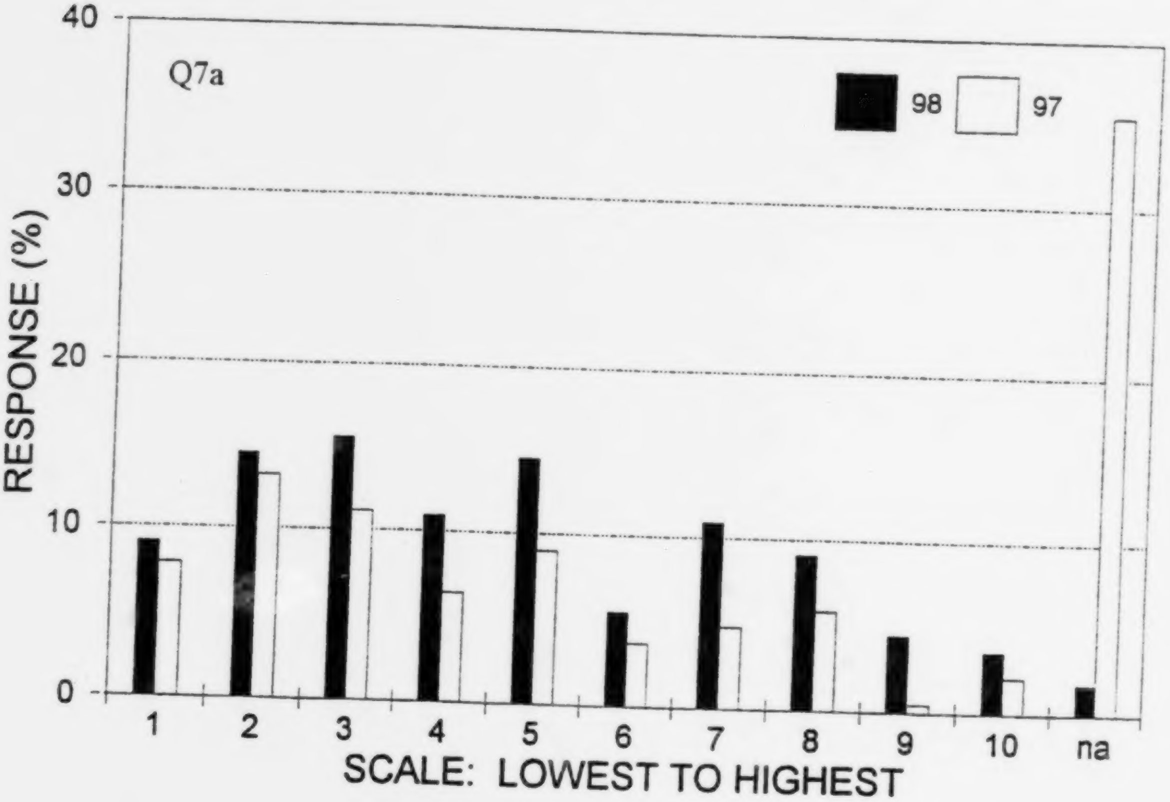

Fig. 7. Response to question 7a concerning the intensity of spawning on an increasing scale of 1 to 10 in 1998 compared to 1997. No answer given (na).

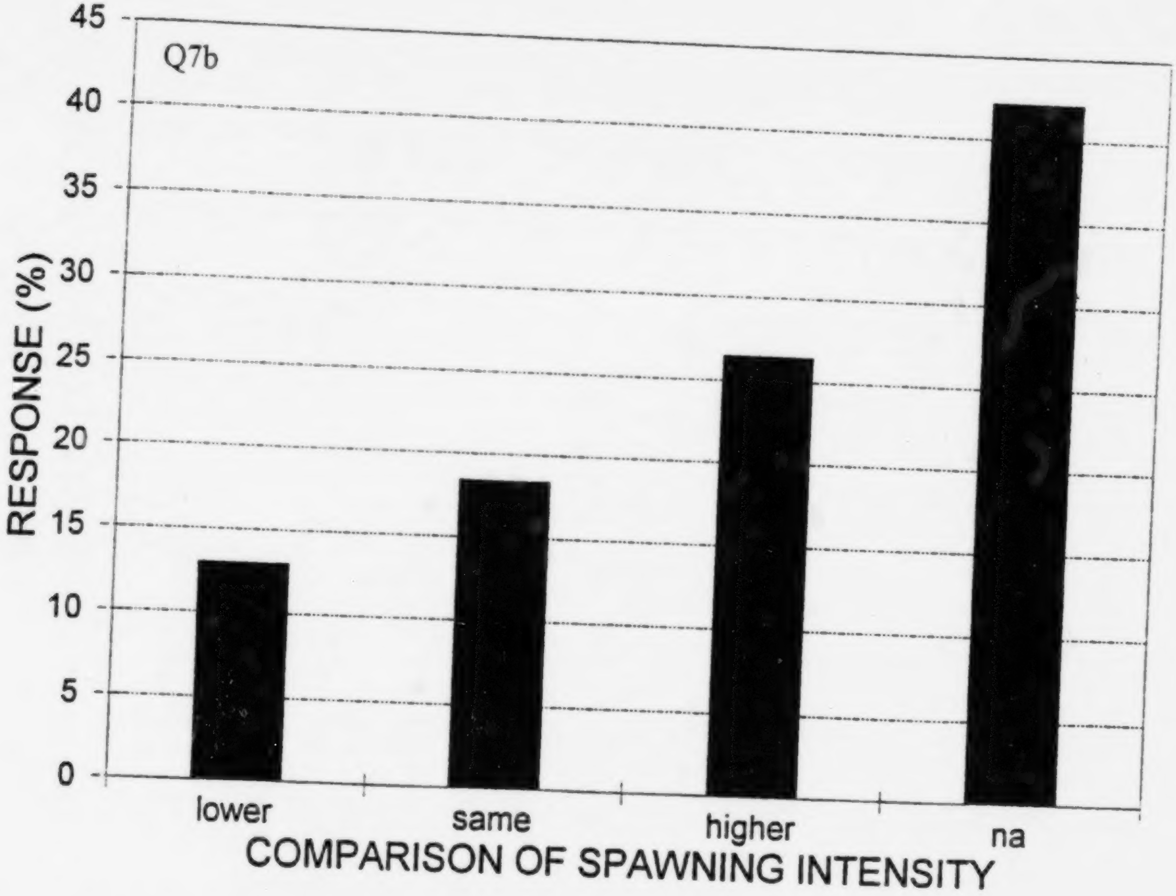

Fig. 8. Response to question 7b comparing the spawning intensity in 1998 relative to 1997. No answer given (na).

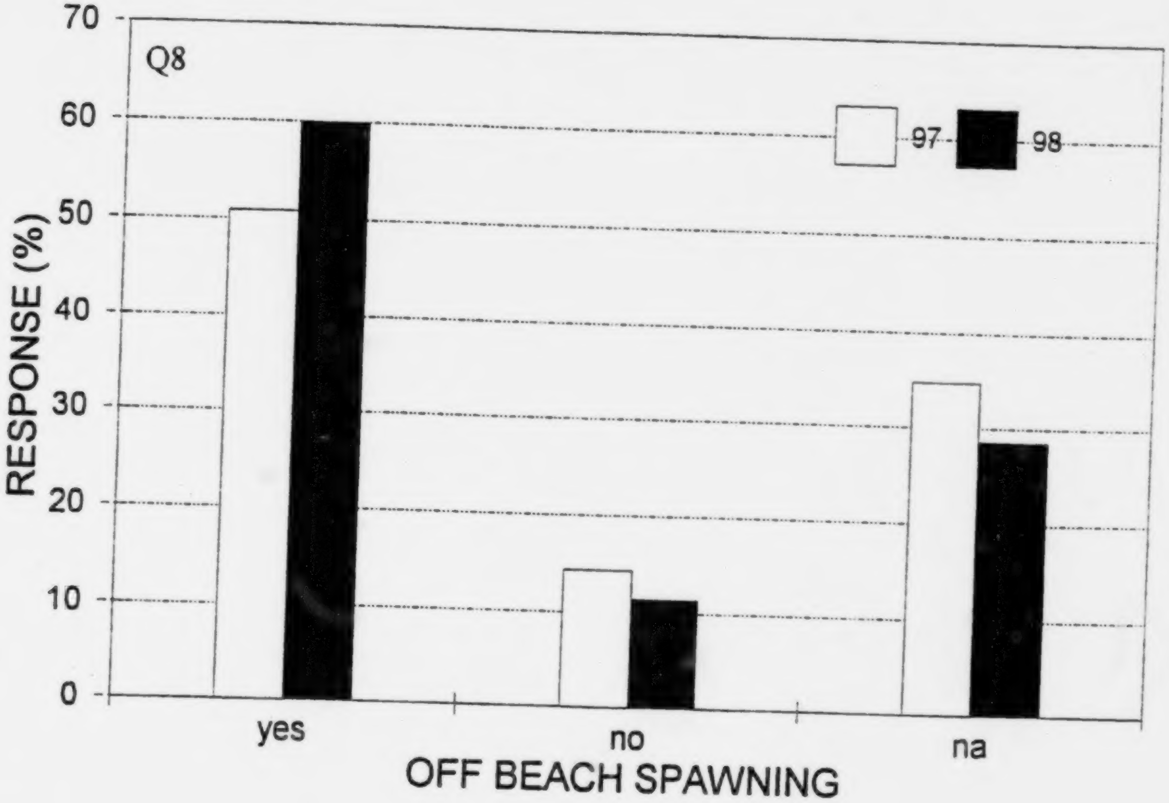

Fig. 9. The extent that off beach spawning occured in 1998 compared to1997 (Nakashima and Clark 1998). No answer given (na).

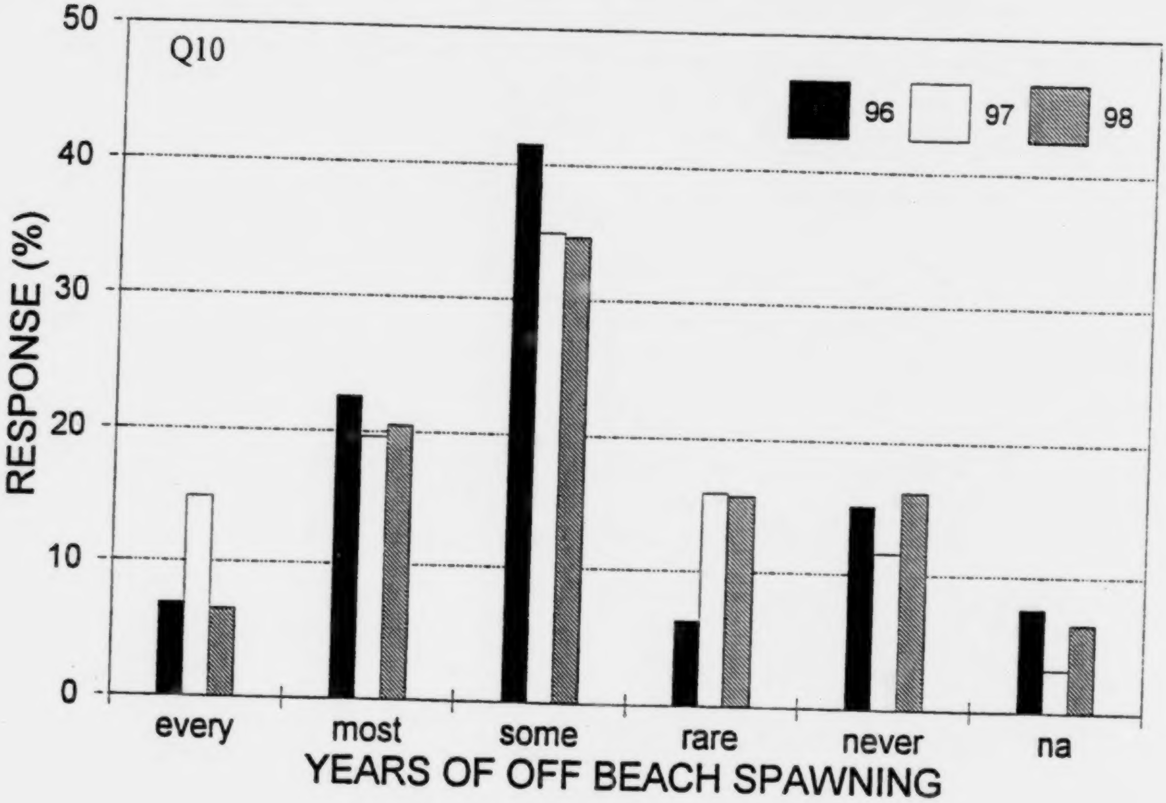

Fig. 10. The prevalence of off beach spawning reported in the 1996, 1997 and 1998 surveys. No answer given (na).

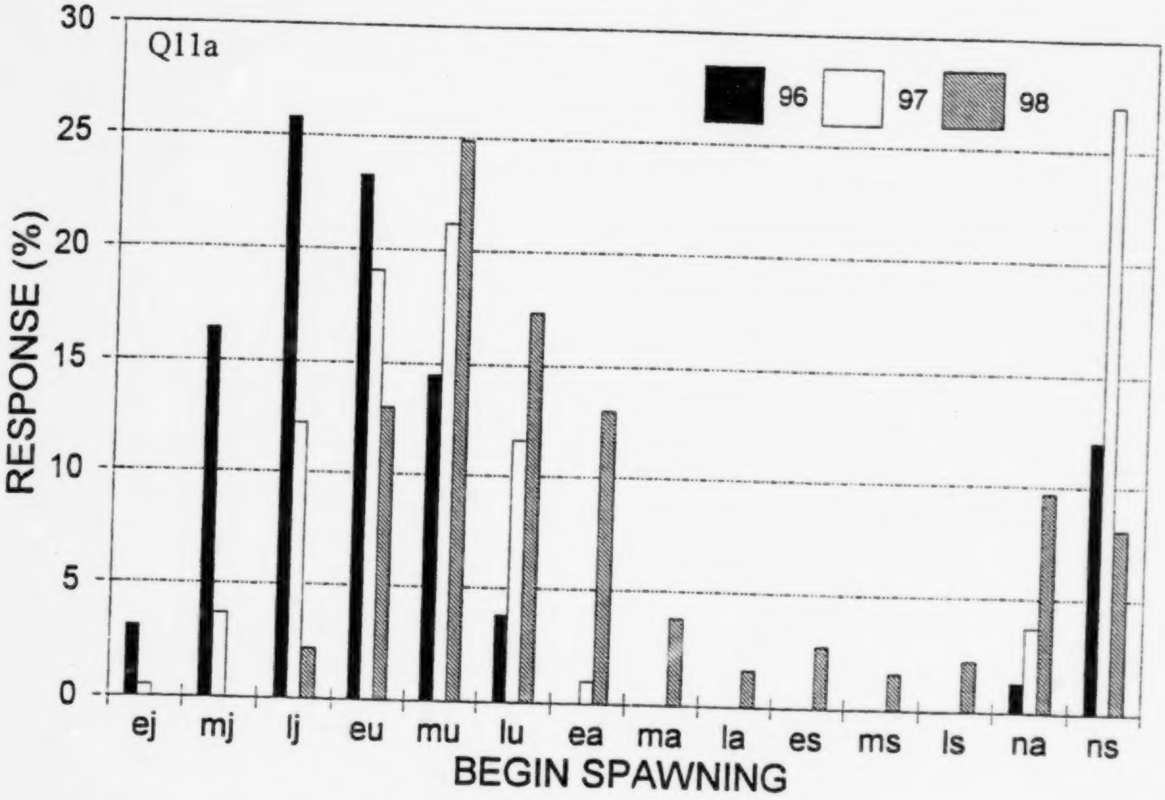

Fig. 11. The time when capelin began spawning in 1996 (Nakashima 1997), 1997 (Nakashima and Clark 1998) and 1998. Spawning times are early June = ej, mid June = mj, late June = lj, early July = eu, mid July = mu, late July = lu, early August = ea, mid August = ma, late August = la, early September = es, mid September = ms, and late September = ls. No answer given (na) and no spawning (ns).

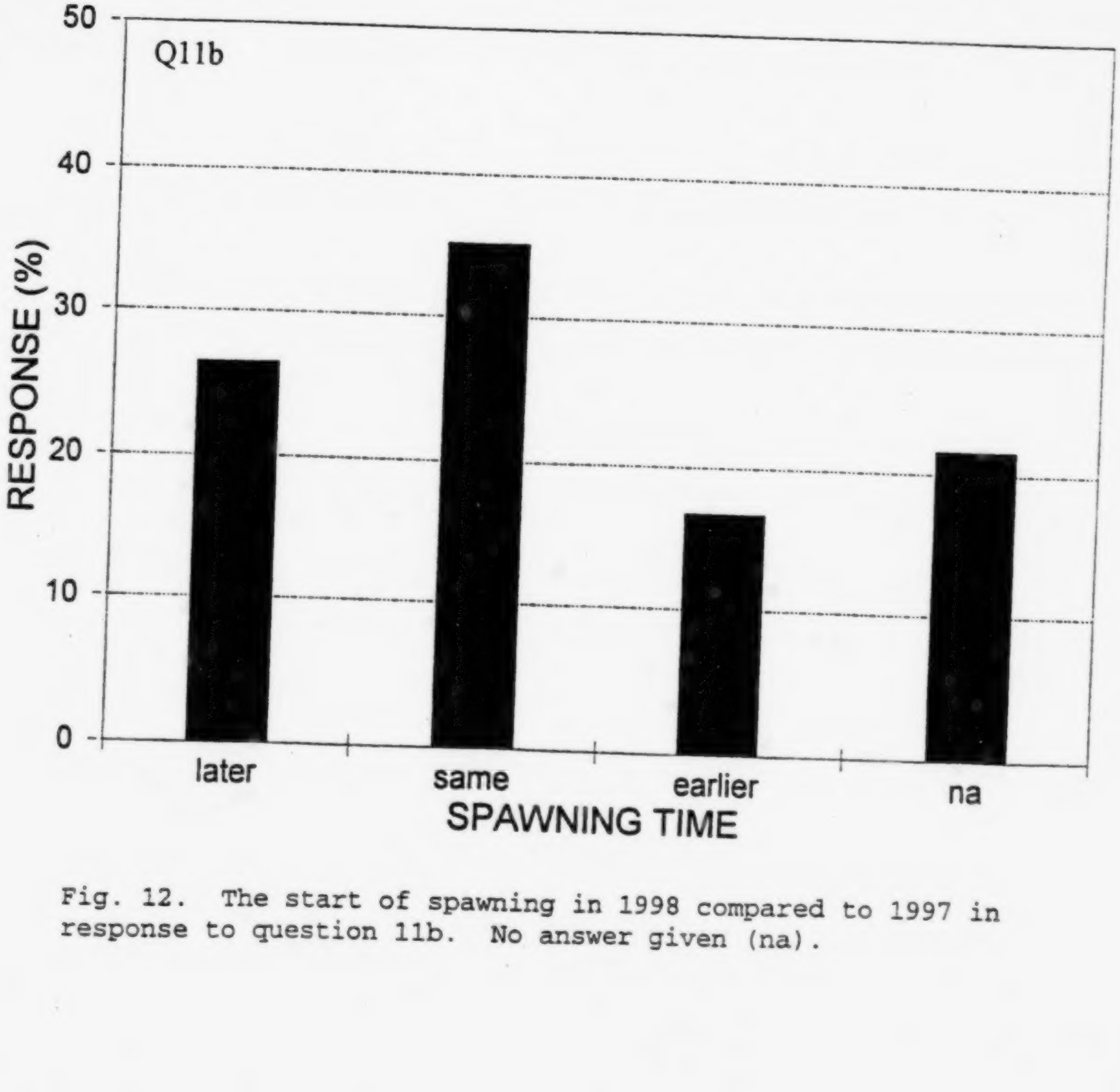

Fig. 12. The start of spawning in 1998 compared to 1997 in response to question 11b. No answer given (na).

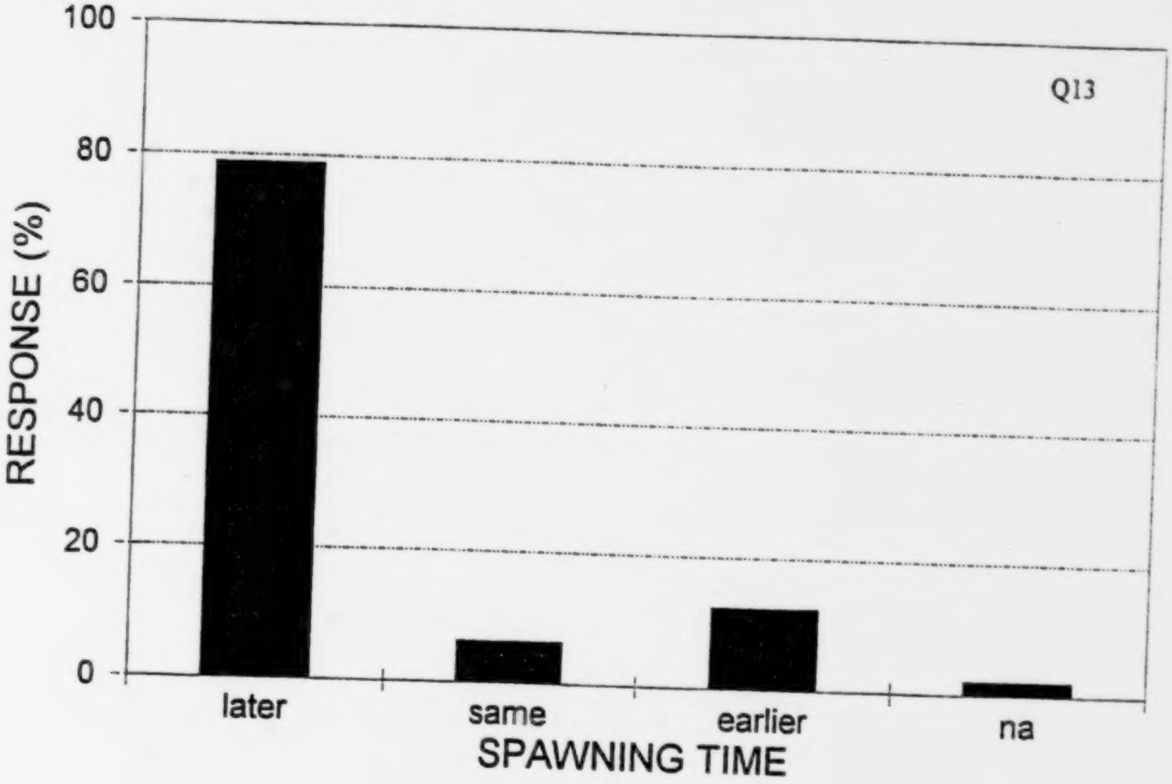

Fig. 13. Comparison of spawning times in 1998 to when respondents first fished capelin. No answer given (na).

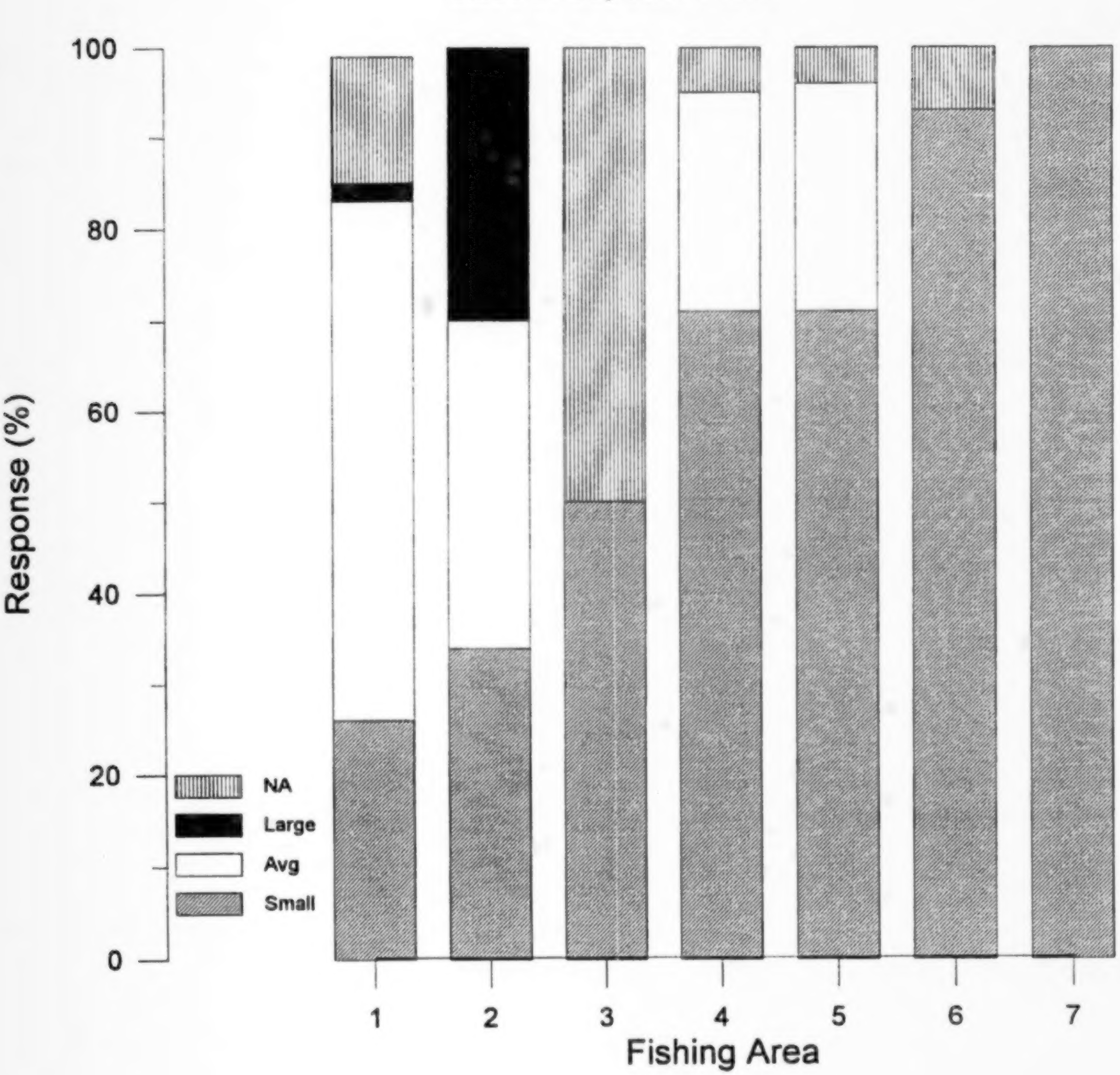

Fig. 14. Sizes of capelin by fishing area (White Bay = 1, Notre Dame Bay = 2, Bonavista Bay = 3, Trinity Bay = 4, Conception Bay = 5, Southern Shore = 6, St. Mary's Bay = 7).

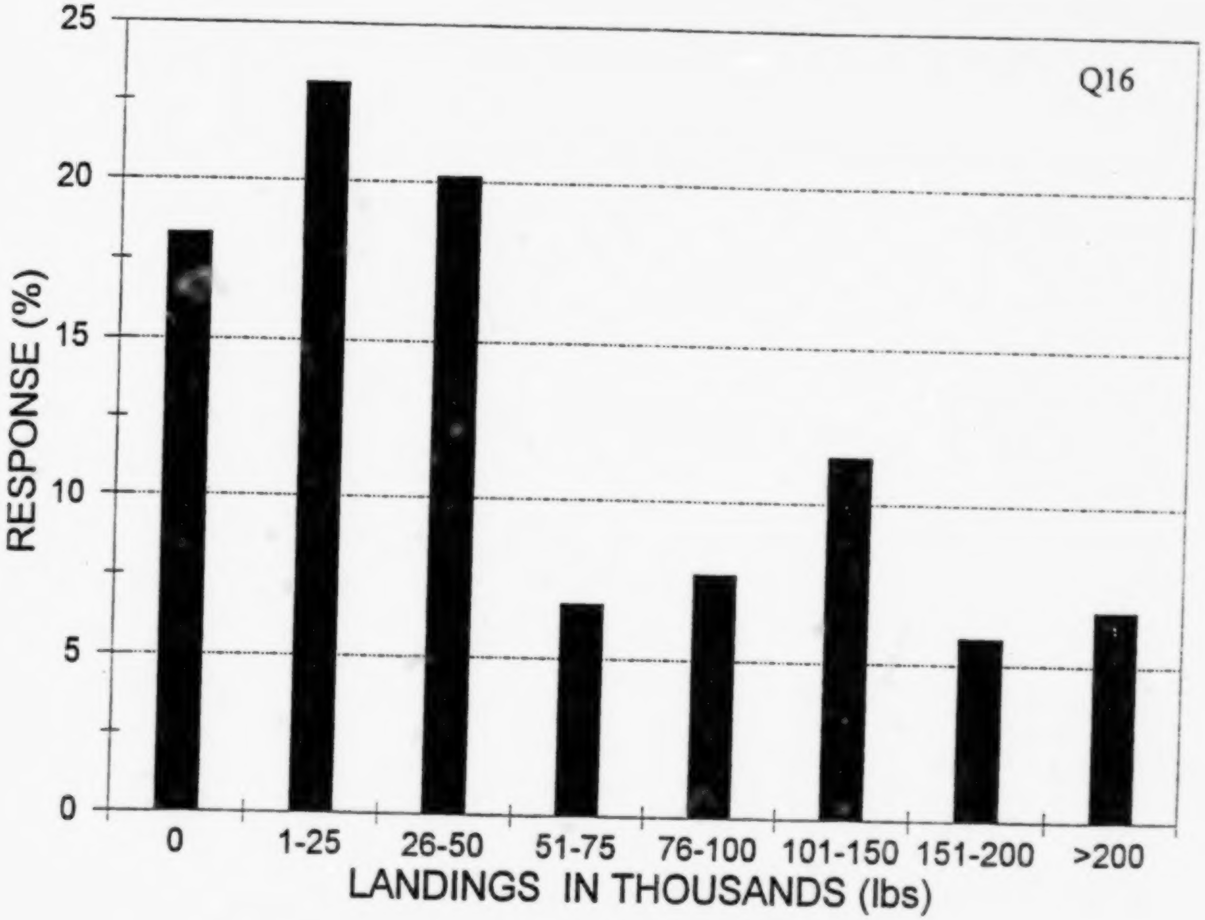

Fig. 15. Estimated landings in 1998 by respondents of question 16.

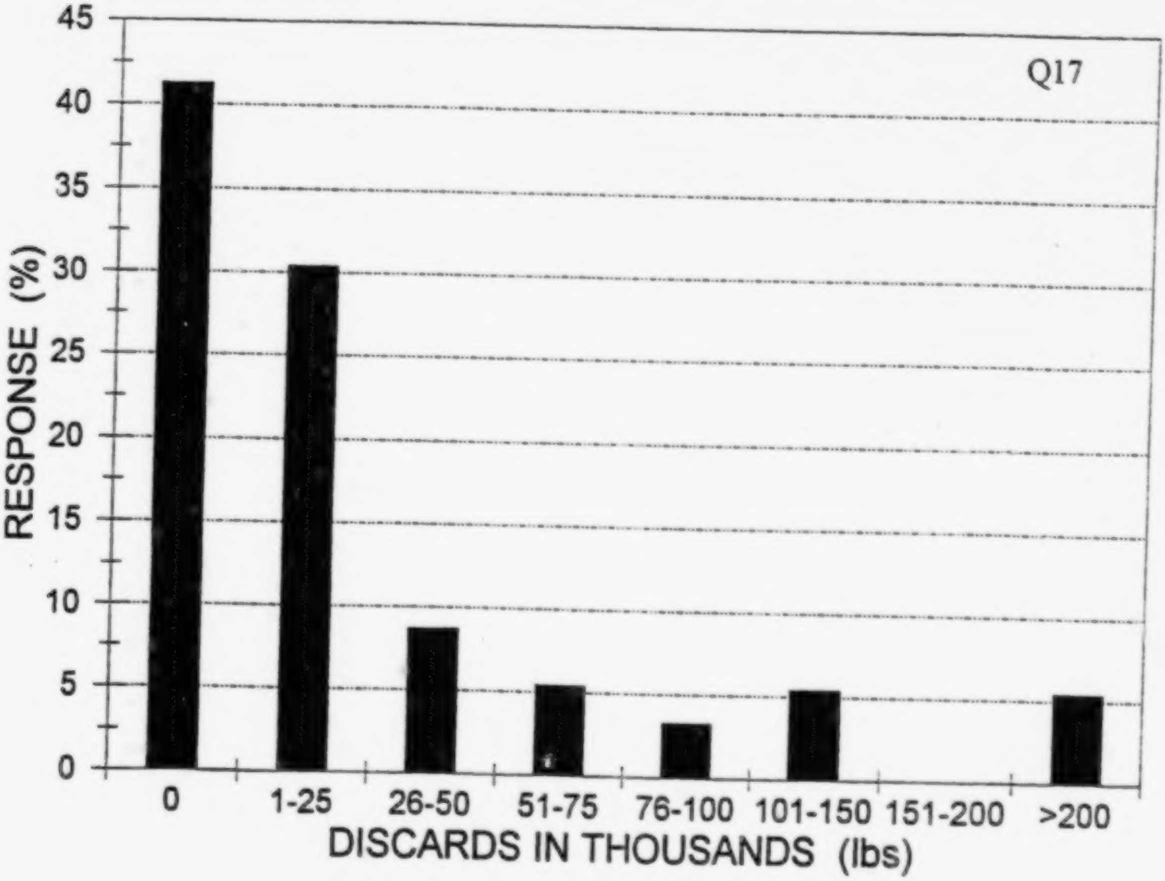

Fig. 16. Estimated discards in 1998 by respondents of question 17.

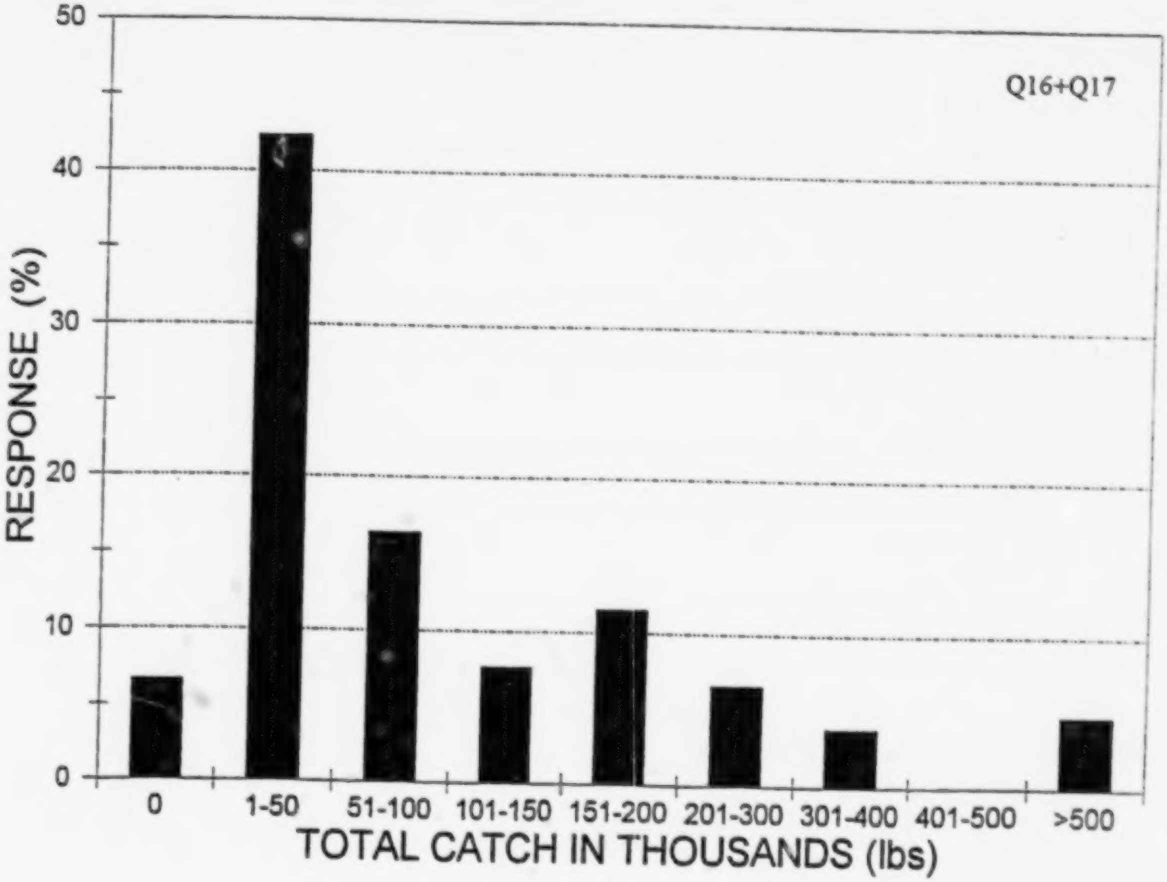

Fig. 17. Estimated total catch in 1998 combining landings and discards.

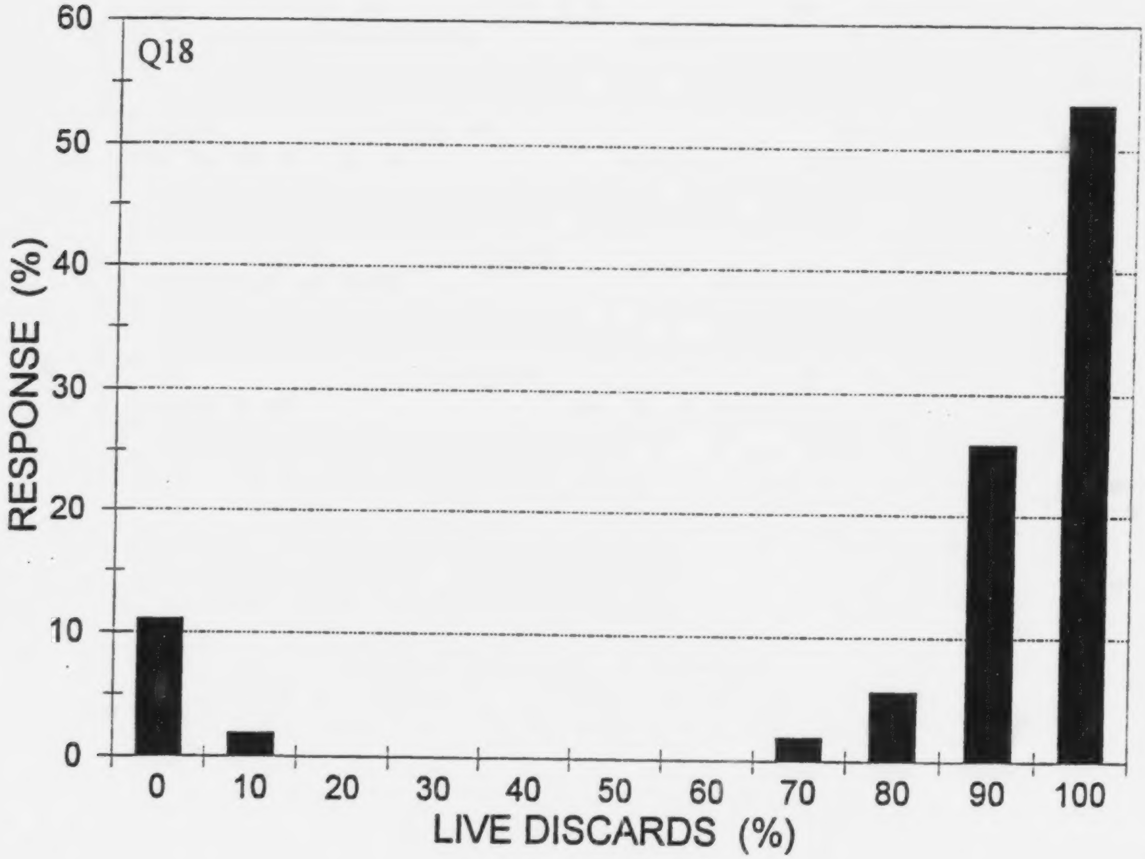

Fig. 18. Estimated survival of discarded capelin by respondent of question 18.

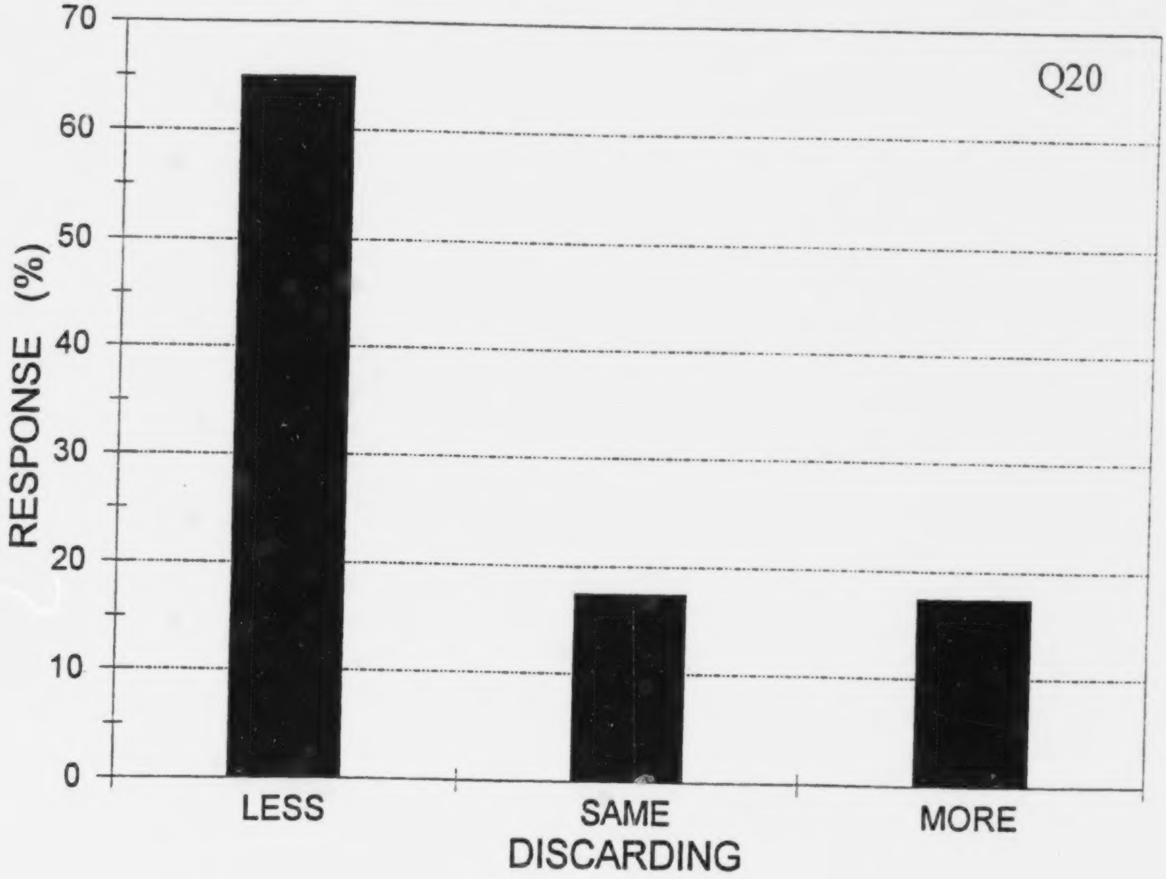

Fig. 19. Comparison of amount of discarding in 1998 compared to earlier years in response to question 20.

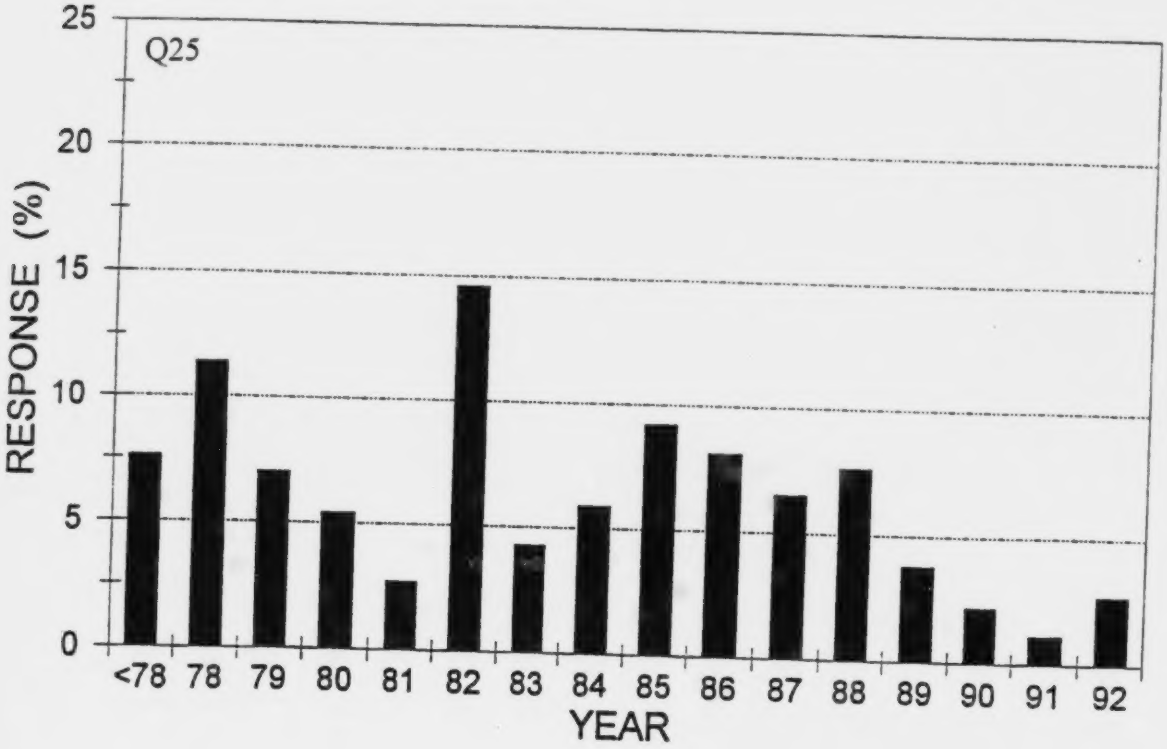

Fig. 20. Experience in the inshore capelin fishery.

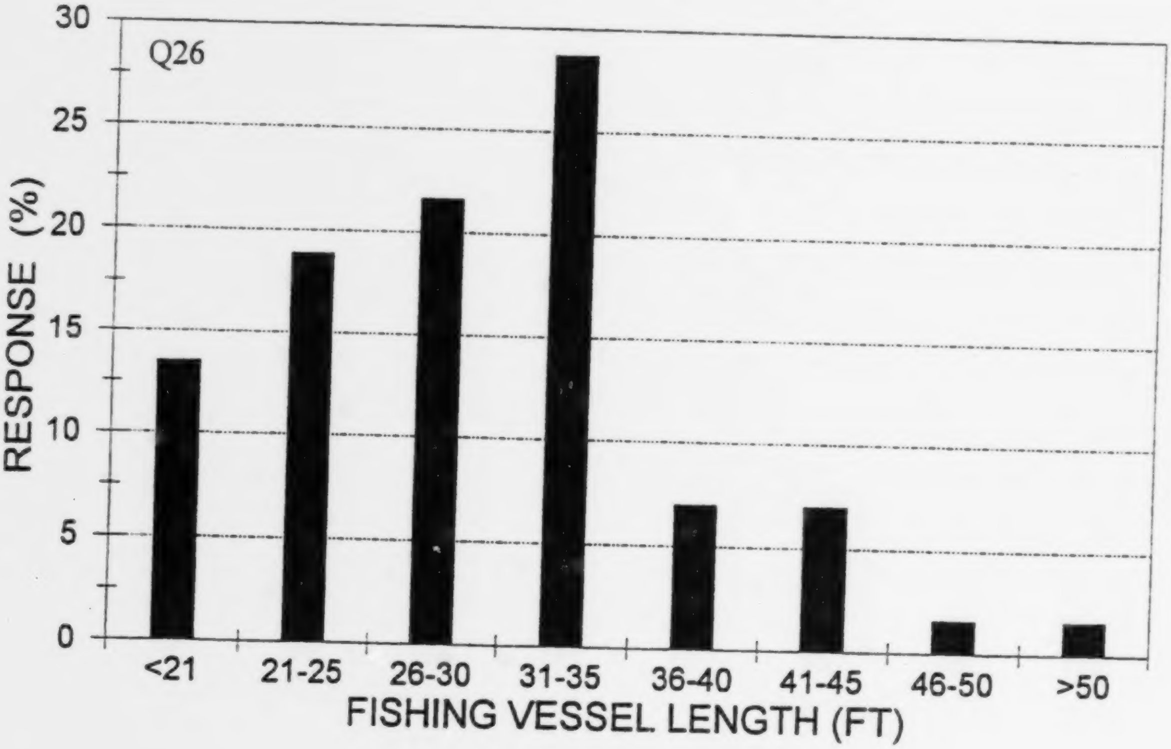

Fig. 21. Lengths of fishing vessels involved in the fixed gear fishery.

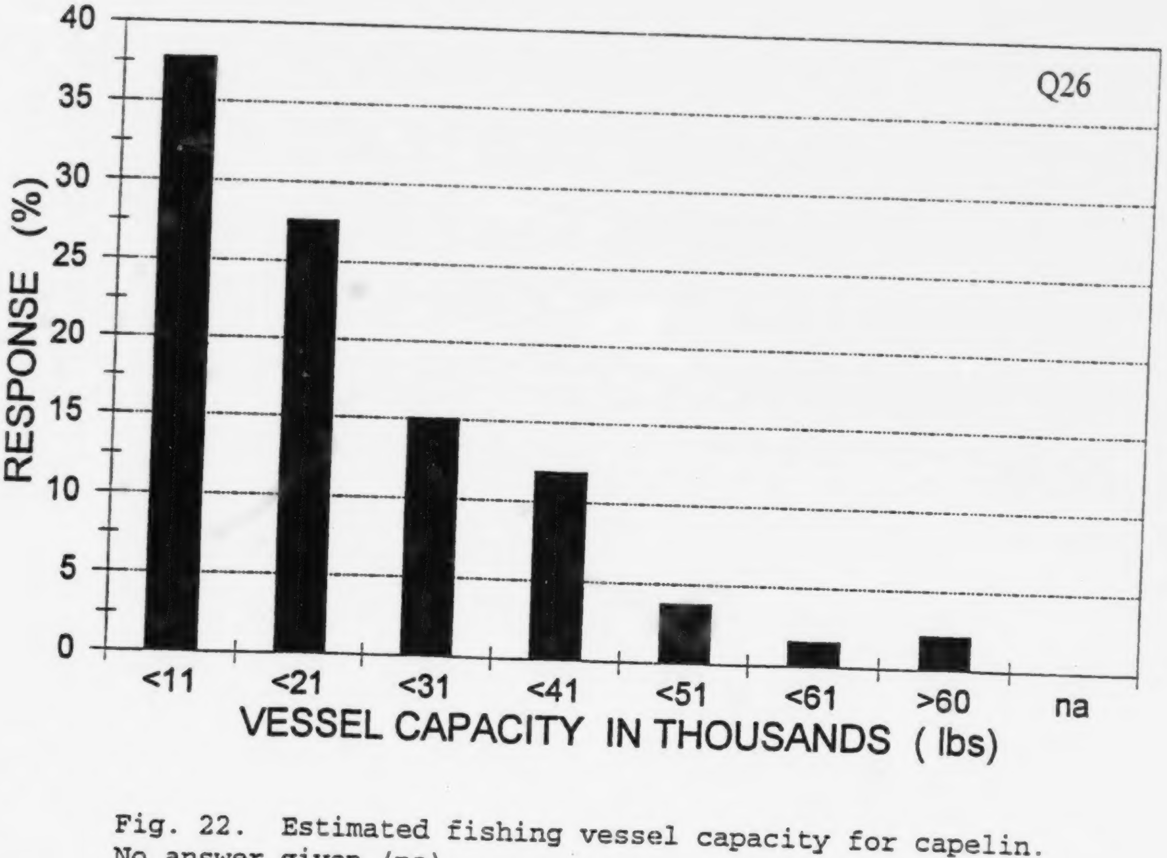

Fig. 22. Estimated fishing vessel capacity for capelin. No answer given (na).

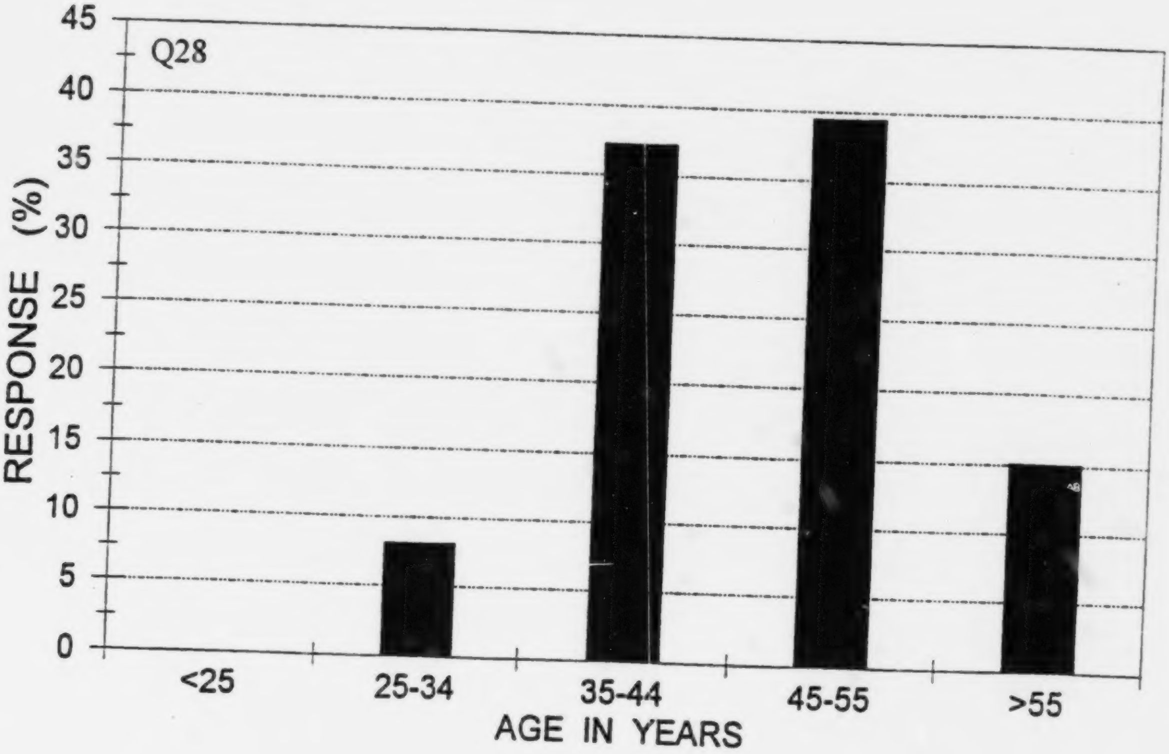

Fig. 23. Age range of capelin fishers in 1998.

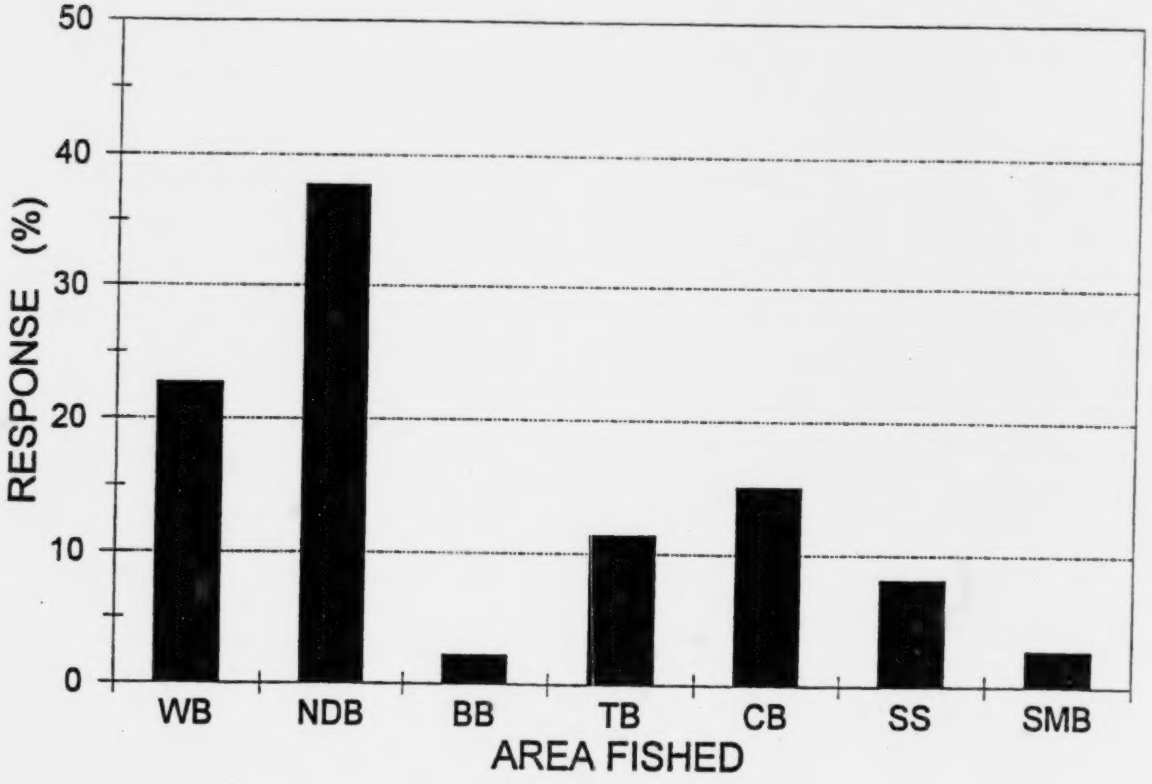

Fig. 24. Distribution of respondents among fishing areas (WB = White Bay, Notre Dame Bay = NDB, BB = Bonavista Bay, TB = Trinity Bay, CB = Conception Bay, SS = Southern Shore, SMB = Trepassey and St. Mary's Bay) for the 1996-98 telephone surveys.

The 1998 Inshore Capelin (Mallotus villosus) Fishery in NAFO Div. 3KL

by

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Introduction

Reported landings based on hails in 1998 were 30,693 t (Table 1) in Div. 2J3KL compared to a quota allocation of 33,280 t (Appendix A). Research logbooks were used to estimate catch and effort for mobile and fixed gear fisheries.

Materials and Methods

Capelin landings are normally extracted from Table M-18, Policy and Economics Branch, however not all purchase slips have been processed from the 1998 fishery to produce the final estimates. Consequently the results for 1998 are based on industry hails, some purchase slips, and commercial logbook records and are to be considered preliminary. Fixed gear landings are not reconciled among gear types.

Research logbooks were mailed to 43 purse seine and 154 fixed gear licensed fishers residing in Div. 3KL. In October 1998, many of the logbooks were collected by staff. Some trap logbooks were completed by fishers who were involved in the monitoring program, however these results are not presented here.

Results and Discussion

The Inshore Fishery

The inshore fishery in Div. 3KL is normally prosecuted by purse seines, capelin traps, and beach seines and has been regulated by quota management since 1982. Quotas by area and gear type established for 1998 are presented in Appendix A. The purse seine fishery opened in all areas on June 30 and continued until the quota was caught or fish specifications failed to meet market criteria (Appendix B). Monitoring programs were established in some areas to open the fishery when fish conformed to criteria defined in the 1998 Capelin Management Plan. The presence of small females in the catch (more than 50 females/kg) was the main reason areas experienced multiple openings and closings in 1998. Unlike 1997 fixed-gear fisheries were opened in Conception Bay, Trinity Bay, Bonavista Bay, and all parts of White Bay and Notre Dame Bay (Fig. 1). The reported landings for 1998 (Table 1) were considerably more than 1997 and amongst the highest in the 1990s (Fig. 2, Table 1). In some areas 'tuck seines' were deployed when fishers observed that capelin stayed in deep water unavailable to traps and beach seines. How these catches are being categorized is unknown at this time.

Research Logbooks

The return rate of completed logbooks was higher than in 1997. Discounting those who did not fish in 1998, 66% of fixed gear and 72% of mobile gear fishers returned research logbooks (Table 2). One fixed gear logbook was returned but the information was insufficient to code into the database. Thirteen fished (five mobile and eight fixed gear) but did not send in a logbook. One fixed gear fisher had no landings and did not fill in his logbook. The higher return rate may be due to the higher catches and greater fishing activity in 1998 and to our efforts in the fall of 1998 to personally visit many of the logbook participants and discuss the events surrounding the 1998 fishery.

The main reasons reported for discarding capelin were variable. The ones mentioned most often were low percentage of females, small size fish, and redfeed (Table 3). In White Bay capelin were discarded from traps because the percentage of females was low and redfeed levels were too high. The reasons for trap discards in the 'miscellaneous' category was a catch in excess of vessel capacity. In Notre Dame Bay small fish was the main problem (69%). In Bonavista Bay redfeed (61%) was often reported as a problem. In Trinity Bay low percentage of females (37%) and small females (31%) were most often mentioned. Low female percentage (65%) was the major reason for trap discards in Conception Bay. The 'miscellaneous'category included discarding because capelin were mixed with herring and gear damage. On the Southern Shore small females (100%) was the only reason reported. For the mobile fleet in White Bay, all discards were fish given away to other vessels which isn't included in Table 3. In Notre Dame Bay low female percentage (55%) and boat quotas (45%) were the reasons purse seine catches were released. Discarding by seiners in Bonavista Bay was due to boat quotas (100%). Redfeed (89%) was the dominant reason capelin were discarded in Trinity Bay by purse seiners. Redfeed (33%), low percentage of females (33%) and small females (26%) were equally important in Conception Bay. In St. Mary's Bay all discards were in the 'miscellaneous' category consisting of mixed sets with herring and amounts too small to land.

Discarding as a percentage of reported landings varied among areas for traps (Table 4: 0% to all discards) and for purse seines (Table 5: 0 to 21%). The overall discarding rate of 58% for traps was lower than in 1997 (Table 6) and the rate of 12% for purse seines was the lowest in the series (Table 7). The reported discards include 68 t given away by purse seiners to other vessels. Excluding fish given away, according to the logbook reports 97% of trap and 88% of purse seine discards were released alive at sea. The remaining 12% of the purse seine discards were discarded dead due to boat quotas. In the present analysis (Tables 3-7) discards are defined as capelin caught but not landed by the fishers who caught them and includes capelin released alive and those dumped as dead fish.

Fishing effort for traps and for purse seines were somewhat higher than the low rates estimated in 1997. Traps averaged 5.4 fishing days and were hauled 11.5 times (Table 6). Purse seines searched for 5.2 days and averaged 9.5 sets (Table 7). While trap logbook data are from all areas, most of the fishing activity was in White Bay, Trinity Bay, and Conception Bay (Table 4). Purse seine logbook data were available from all areas (Table 5).

Catch/effort (CPUE) estimates were available since 1981 for traps and for purse seines (Tables 6 and 7). The 1998 trap CPUE of 6.2 t/day was lower than in 1997 and equivalent to the series (1981-1997) average of 6.1. The estimate of 2.9 t/haul was less than the series average of 3.5. The 1998 purse seine CPUE of 21.0 t/day was one of the highest in the series and the CPUE of 11.5 t/set was higher than the series (1981-1997) average of 10.0.

Conclusions

Discarding varied among areas and gear types. Discarding was 58% from traps and 12% from purse seines indicating that capelin caught by the mobile fleet was more likely to have met market demands. Most were reported as released live at sea. The main reasons for releasing capelin were low percentage of females, redfeed, and small females. Boat quotas were an important consideration for purse seiners. The 1998 trap and purse seine CPUEs were lower than 1997 in the C/D series. The purse seine C/S was among the higher ones in its C/S series and the trap C/H was one of the lower ones in the C/H series. When staff were meeting with logbook participants in the fall many fixed gear fishers reported that capelin stayed off in deeper water and were unavailable to capelin traps. In some areas fishers used 'tuck' seines to fish capelin. Last year we suspected that fishing in recent years was very different than in the 1980s (Nakashima and Slaney 1998). Even though effort increased slightly from 1997, trap and purse seine effort remains low (Fig. 3, 4). Trap fishing days and purse seine searching time is low in the 1990s primarily due to monitoring initiatives put in place to reduce discarding of unmarketable capelin. The effect on fishing effort has been to concentrate the effort only when capelin are highly available and to reduce fishing time dramatically. This reduction especially in recent years is so severe that no method has been proposed to utilize the catch rate data in recent years as indicators of stock abundance (Nakashima 1998; Nakashima and Slaney 1998).

Acknowledgments

The continuing support of those who have participated in the research logbook program has provided valuable insights about the fishery and fishing. M. Y. Farrell assisted in the preparation of the manuscript.

References

Nakashima, B. S. 1998. Relative multiplicative trends in biomass, cohort abundance, and recruitment of capelin (Mallotus villosus). pp. 134-152. In: Anon. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 98/63.

Nakashima, B. S and B. W. Slaney. 1998. The 1997 inshore capelin (Mallotus villosus) fishery in NAFO Div. 3KL. pp. 38-49. In: Anon. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 98/63.

Table 1. Inshore capelin landings (t) by fishing gear (vessels <21 m in length) by area (White Bay = WB, Notre Dame Bay = NDB, Bonavista Bay = BB, Trinity Bay = TB, Conception Bay = CB, Southern Shore = SS, St. Mary's and Trepassey Bays = SMB) and by NAFO Division.

Year	Div.	Area	Purse seine	Beach seine	Trap	Dipnet	Total
1989	**2J**		**0**	**3**	**304**		**307**
		WB	3276	643	9513		13432
		NDB	3235	2793	7938		13966
	3K		**6511**	**3436**	**17451**		**27398**
		BB	2800	111	4426		7337
		TB	4822	172	14845		19839
		CB	8643	75	8579		17297
		SS	225	10	3048		3283
		SMB	3327	1	643		3971
	3L		**19817**	**369**	**31541**		**51727**
1990	**2J**		**0**	**1**	**0**		**1**
		WB	4507	318	11820		16645
		NDB	5782	3403	9294		18479
	3K		**10289**	**3721**	**21114**		**35124**
		BB	3186	90	5619		8895
		TB	4790	108	11723		16621
		CB	6470	41	11381		17892
		SS	31	45	2897		2973
		SMB	610	0	1016		1626
	3L		**15087**	**284**	**32636**		**48007**
1991	**2J**		**0**	**1**	**0**		**1**
		WB	239	227	12045		12511
		NDB	426	2709	4291		7426
	3K		**665**	**2937**	**16336**		**19937**
		BB	3066	70	3180		6316
		TB	4450	154	6474		11078
		CB	1889	20	2925		4834
		SS	0	7	0		7
		SMB	69	0	3		72
	3L		**9474**	**251**	**12582**		**22307**
1992	**2J**		**0**	**0**	**0**		**0**
		WB	2995	126	7602		10723
		NDB	2819	1113	1695		5627
	3K		**5814**	**1239**	**9297**		**16350**
		BB	977	28	60		1065
		TB	69	26	53		148
		CB	411	57	160		628
		SS	0	5	21		26
		SMB	25	3	26		54
	3L		**1482**	**119**	**320**		**1921**
1993	**2J**		**0**	**1**	**0**		**1**
		WB	1583	197	5108		6888
		NDB	1447	2503	2323		6273
	3K		**3030**	**2700**	**7431**		**13161**
		BB	1734	92	1920		3746
		TB	1989	365	4568		6922
		CB	4712	50	3377		8139
		SS	57	31	1480		1568
		SMB	2102	4	404		2510
	3L		**10594**	**542**	**11749**		**22885**

Table 1. Continued ...

Year	Div.	Area	Purse seine	Beach seine	Trap	Dipnet	Total
1994	**2J**		**0**	**0**	**0**		**0**
		WB	0	20	0		20
		NDB	23	23	1		47
	3K		**23**	**43**	**1**		**67**
		BB	0	2	0		2
		TB	23	54	4		81
		CB	0	4	10		14
		SS	0	16	722		738
		SMB	0	3	55		58
	3L		**23**	**79**	**791**		**893**
1995*	**2J**		**0**	**0**	**0**	**0**	**0**
		WB	0	2	0	0	2
		NDB	0	25	1	2	28
	3K		**0**	**27**	**1**	**2**	**30**
		BB	0	35	0	5	40
		TB	0	16	1	4	21
		CB	0	19	2	1	22
		SS	0	9	0	0	9
		SMB	0	6	0	0	6
	3L		**0**	**85**	**3**	**10**	**98**
1996*	**2J**		**15**	**0**	**7**	**0**	**22**
		WB	1278	1	3462	0	4741
		NDB	1258	1121	1772	0	4151
	3K		**2551**	**1122**	**5241**	**0**	**8914**
		BB	1204	9	1942	0	3155
		TB	1906	31	2934	1	4872
		CB	3242	14	3774	0	7030
		SS	8	0	90	0	98
		SMB	1129	16	535	0	1680
	3L		**7489**	**70**	**9275**	**1**	**16835**
1997*	**2J**		**14**	**0**	**0**		**14**
		WB	2964	139	3178		6281
		NDB	1558	886	508		2952
	3K		**4522**	**1025**	**3686**		**9233**
		BB	463	0	0		463
		TB	468	8	4		480
		CB	639	0	0		639
		SS	17	0	127		144
		SMB	1832	0	3		1835
	3L		**3419**	**8**	**134**		**3561**
1998**	**2J**		**0**	**0**	**0**		**0**
		WB	2136		4371		6507
		NDB	1720		2189		3909
	3K		**3856**		**6560**		**10416**
		BB	1564		1290		2854
		TB	2190		5220		7410
		CB	3512		3724		7236
		SS	77		408		485
		SMB	1920		372		2292
	3L		**9263**		**11014**		**20277**

* provisional

** quota report

Table 2. Summary of inshore commercial samples processed and aged from 1998 in Div. 3KL.

Gear type	No. of LSM/strat. samples	No. of otoliths aged (N)	Mean no. otoliths ± SD per sample
Div. 3K			
Purse seine	9	262	29.1 ± 2.4
Capelin trap	11	355	32.3 ± 4.0
Beach seine	6	196	32.7 ± 2.8
TOTAL	26	813	
Div. 3L			
Purse seine	18	577	32.1 ± 3.5
Capelin trap	26	827	31.8 ± 3.6
Beach seine	2	63	31.5 ± 2.1
TOTAL	46	1467	

Table 3. Age compositions (%) of capelin from the inshore commercial capelin fishery, Div. 3KL.

Year/Sex	Age				
	2	3	4	5	6
Males					
1982	+	90.5	8.7	0.7	+
1983	0.3	60.8	38.5	0.3	0
1984	0.3	36.0	62.9	0.8	0
1985	4.9	65.4	27.9	1.7	+
1986	0.2	56.7	42.5	0.5	0
1987	0.2	11.4	86.8	1.5	0
1988	3.7	70.2	23.1	3.0	0
1989	0.3	76.8	22.8	0.1	0
1990	0.4	33.6	65.7	0.2	0
1991	9.2	47.8	41.6	1.4	+
1992	7.9	81.4	10.5	0.2	0
1993	5.9	88.4	5.6	0.1	0
1994[a]	23.8	56.7	19.5	0	0
1995[b]	34.7	63.4	1.9	0	0
1996	25.0	73.4	1.5	0	0
1997	58.7	34.1	7.1	0	0
1998	33.9	60.0	3.5	0	0
Females					
1982	1.5	77.9	12.4	6.4	1.8
1983	5.8	58.8	33.4	2.0	+
1984	2.6	41.0	48.0	8.1	0.3
1985	13.4	57.3	18.5	10.3	0.5
1986	0.2	65.5	29.5	3.7	1.1
1987	4.8	19.1	67.1	8.5	0.4
1988	11.6	51.8	12.1	23.0	1.5
1989	1.3	70.7	23.4	2.0	2.6
1990	1.4	44.1	51.9	2.5	+
1991	12.6	49.5	29.4	8.4	0.1
1992	17.6	67.8	12.9	1.7	+
1993	10.4	82.1	7.3	0.2	+
1994[a]	33.4	43.1	19.7	3.8	0
1995[b]	55.8	37.3	6.4	0.4	0.1
1996	33.3	58.1	8.5	0.2	0
1997	47.7	22.5	25.1	4.7	0
1998	48.3	39.3	8.0	1.4	0
Sexes combined					
1982	0.7	84.6	10.5	3.4	0.8
1983	3.3	59.7	35.7	1.3	+
1984	1.5	38.6	55.2	4.5	0.2
1985	10.1	60.4	22.1	7.0	0.4
1986	0.2	62.1	34.5	2.5	0.7
1987	2.9	15.9	75.5	5.5	0.2
1988	8.4	59.1	16.5	15.1	0.9
1989	0.8	73.5	23.1	1.2	1.4
1990	1.0	39.7	57.8	1.5	+
1991	11.1	48.8	34.5	5.5	0.1
1992	13.3	73.9	11.8	1.0	+
1993	8.5	84.8	6.6	0.1	+
1994[a]	31.1	46.3	19.7	2.9	0
1995[b]	43.7	52.3	3.8	0.2	0
1996	29.9	64.4	5.6	0.1	0
1997	52.2	27.3	17.8	2.8	0
1998	42.0	48.3	6.0	0.8	0

[a] low sample numbers (N = 11) and from a small area

[b] research samples, no commercial samples collected

Table 4. The distribution of research logbooks in 1998.

NAFO Div.	Gear type	No. of fishers	No. returned	No. never fished	No logbook
3K	Mobile	17	11	5	1
	Fixed	57	21	21	15[a]
3L	Mobile	26	15	2	9[b]
	Fixed	97	40[c]	40	17[d]

a - 1 fished trap, no landings, and no logbook completed
- 1 searched few days but no capelin, beach seine logbook

b - 5 fished, landed capelin, but did not complete logbook

c - 1 returned log but information incomplete to include in analysis

d - 7 fished but didn't complete logbook

Table 5. Percent contribution by weight of reasons for discarding capelin in 1998. This analysis excludes capelin given to other fishers.

Area	Redfeed	Low % females	Small females	Males picked out	Females spawned out	Boat quota/ quota filled	Misc.	Not given
Traps:								
White Bay	33	39	1	1	0	16	10	0
Notre Dame Bay	17	14	69	0	0	0	0	0
Bonavista Bay	61	0	38	0	0	0	1	0
Trinity Bay	14	37	31	0	8	3	6	0
Conception Bay	0	65	4	0	5	0	26	0
Southern Shore	0	0	100	0	0	0	0	0
St. Mary's Bay	0	0	0	0	0	0	0	0
Purse seine:								
White Bay	0	0	0	0	0	0	0	0
Notre Dame Bay	0	55	0	0	0	45	0	0
Bonavista Bay	0	0	0	0	0	100	0	0
Trinity Bay	89	0	9	0	0	2	0	0
Conception Bay	33	33	26	0	0	7	1	0
St. Mary's Bay	0	0	0	0	0	0	100	0

Table 6. Capelin landings (t), discards (t), and catch/effort from research logbook records for capelin traps in Div. 3KL in 1998.

Area	No. fishers	No. traps	Landings	Discard logbook	Bycatch		No. days fished (D)	No. times hauled (H)	C = Landings + discards	
					Cod	Herring			C/D	C/H
White Bay	13	18	340.5	109.4	2.6	6.1	83.6	195	5.4	2/3
Notre Dame Bay	2	2	0	7.9	0.3	+	2.6	6	3.0	1.3
Bonavista Bay	4	4	30.8	35.8	10.0	+	23.7	49	2.8	1.4
Trinity Bay	17	28	747.6	346.7	3.2	+	118.9	323	9.2	3.4
Conception Bay	12	18	389.3	384.2	7.9	28.3	154.0	246	5.0	3.1
Southern Shore	1	1	0	19.1	0.5	+	4.5	8	4.2	2.4
St. Mary's Bay	2	2	40.4	5.4	0	0	6.5	13	7.0	3.5

Table 7. Capelin landings (t), discards (t), bycatch (t), and catch/effort compiled from research logbooks for purse seines in Div. 3KL in 1998.

Area	No. of fishers	Landings By logbook	Discards by logbook*	No. days fished	No. sets made	C = landings + discards	
						C/D	C/S
White Bay	10	342.9	49.9	18	24	21.8	16.4
Notre Dame Bay	10	300.7	24.9	20	26	16.3	12.5
Bonavista Bay	6	385.6	22.7	9	24	45.4	17.0
Trinity Bay	14	398.3	85.3	22	36	22.0	13.4
Conception Bay	22	747.7	107.3	47	98	18.2	8.7
Southern Shore	1	13.6	0	1	2	13.6	6.8
St. Mary's Bay	9	344.7	5.4	18	37	19.5	9.5

* includes capelin given to other fishers

Table 8. Capelin landings (t), discards (t), bycatch (t), and catch/effort from research logbook records for capelin traps in Div. 3KL, 1981-93, 1996-98. Data available from Div. 3L only for 1981 and 1982.

Year	No. fishers	No. traps	Landings	Discard logbook	Bycatch		No. days fished (D)	No. Times Hauled (H)	C = Landings + discards	
					Cod	Herring			C/D	C/H
1981	35	41	1281.0	417.7	6.4	0	577	680	2.9	2.5
1982	60	81	4366.5	605.2	58.5	0	1630	1996	3.1	2.5
1983	50	71	3051.2	1338.0	30.1	38.5	1277	1460	3.4	3.0
1984	67	89	4172.5	634.1	45.1	0.4	1615	2442	3.0	2.0
1985	60	80	3011.3	1850.1	34.2	0.2	1108	1508	4.4	3.2
1986	64	91	5056.4	1436.4	18.0	0.5	1567	2095	4.8	3.6
1987	68	93	3150.6	2437.5	11.5	+	622	1104	9.0	5.1
1988	86	125	6792.6	1500.4	35.9	1.1	1353	2415	6.1	3.4
1989	102	154	6275.8	2188.1	55.5	0.2	1314	2431	6.4	3.5
1990	106	167	5538.1	2986.6	10.7	1.9	1041	1825	9.2	5.3
1991	59	76	2793.0	1187.5	16.7	1.5	860	1325	5.9	3.8
1992	28	34	1225.8	567.1	1.5	5.7	297	666	6.0	2.7
1993	59	78	2261.1	297.0	20.7	37.0	400	863	6.4	3.0
1996	52	68	1719.4	930.8	79.2	3.6	274	692	9.7	3.8
1997	17	22	516.3	384.7	5.5	6.6	84	198	10.7	4.6
1998	51	73	1548.6	903.1	24.5	34.4	394	840	6.2	2.9

Table 9. Capelin landings (t), discards (t), and catch/effort from research logbook records for purse seines in Div. 3KL, 1981-93, 1996-98.

Year	No. fishers	Landings	Discards logbook	No. days fished (D)	No. sets Made (S)	C = landings + discards	
						C/D	C/S
1981	23	2705.3	810.4	376	707	9.4	5.0
1982	61	11541.9	2484.8	859	1670	16.3	8.4
1983	48	6439.0	4551.3	626	1155	17.6	9.5
1984	46	8185.5	1517.2	679	1305	14.3	7.4
1985	35	4191.0	2314.3	396	696	16.4	9.3
1986	36	8654.5	2745.2	605	991	18.8	11.5
1987	29	2100.5	869.1	169	267	17.6	11.1
1988	41	8282.7	1247.1	476	927	20.0	10.3
1989	46	7463.5	1687.1	421	863	21.7	10.6
1990	32	5081.4	2327.4	344	630	21.5	11.8
1991	9	699.0	413.7	74	95	15.0	11.7
1992	17	1719.8	254.0	95	146	20.8	13.5
1993	21	2448.7	291.5	169	292	16.2	9.4
1996	23	1327.9	396.6	101	181	17.1	9.5
1997	27	1489.8	648.7	91	192	23.5	11.1
1998	26	2533.5	300.9	135	247	21.0	11.5

Appendix A

1998 Capelin Allocations

NAFO Area	Coastal area	Quotas (tonnes)		
		Fixed gear	Purse seine	Total
2J	Labrador	150	-	150
3K	White Bay	4475	1500	5975
	Notre Dame Bay	3925	1500	5425
Totals - 3K		8400	3000	11400
3L	Bonavista Bay	2245	1425	3670
	Trinity Bay	4490	1870	6360
	Conception Bay	3710	3370	7080
	Southern Shore	2300	190	2490
	St. Mary's Bay	450	1680	2130
Totals - 3L		13195	8535	21730

1998 Capelin Quotas - Fixed Gear Sub-divisions

Area	Sub-division	Quota
White Bay	Cape Bauld to Fischot Island	965
	Fischot Island to Cape Fox	325
	Cape Fox to Hampden, inclusive	1274
	Bottom of Bay to Cape St. John	1911
Notre Dame Bay	Cape St. John to North Head	1105
	North Head to Dog Bay Point	2300
	Dog Bay Point to Cape Freels	520
Southern Shore	Cape St. Francis to Long Point	600
	Long Point to Cape Neddick	400
	Cape Neddick to Cape Pine	1300

Appendix B

1998 Opening and Closing Dates

Mobile Gear

St. Mary's Bay - June 30-July 1

Southern Shore - June 30-July 2

Conception Bay - June 30-July 4, July 9

Trinity Bay - June 30-July 7, July 15

Bonavista Bay - June 30-July 12, July 20

Notre Dame Bay - June 30-July 25

White Bay - June 30-July 2

Fixed Gear

St. Mary's Bay - June 30-July 4

Southern Shore:
  Cape St. Francis to Long Point - July 7-24
  Long Point to Cape Neddick - July 8-17
  Cape Neddick to Cape Pine - July 3-16

Conception Bay - July 9-22

Trinity Bay - July 14, July 16-20

Bonavista Bay - June 26-August 7 (except Cannings Cove to Cape Bonavista - June 26-July 26, July 30-August 7)

Notre Dame Bay:
  Cape St. John to North Head - July 13-15
  North Head to Dog Bay Point - July 7-August 5
  Dog Bay Point to Cape Freels - July 7-31

White Bay:
  Cape Bauld to Fischot Island - July 4-29
  Fischot Island to Cape Fox - July 4-9
  Cape Fox to Hampden - July 2-6
  Hampden to Cape St. John - July 9-15

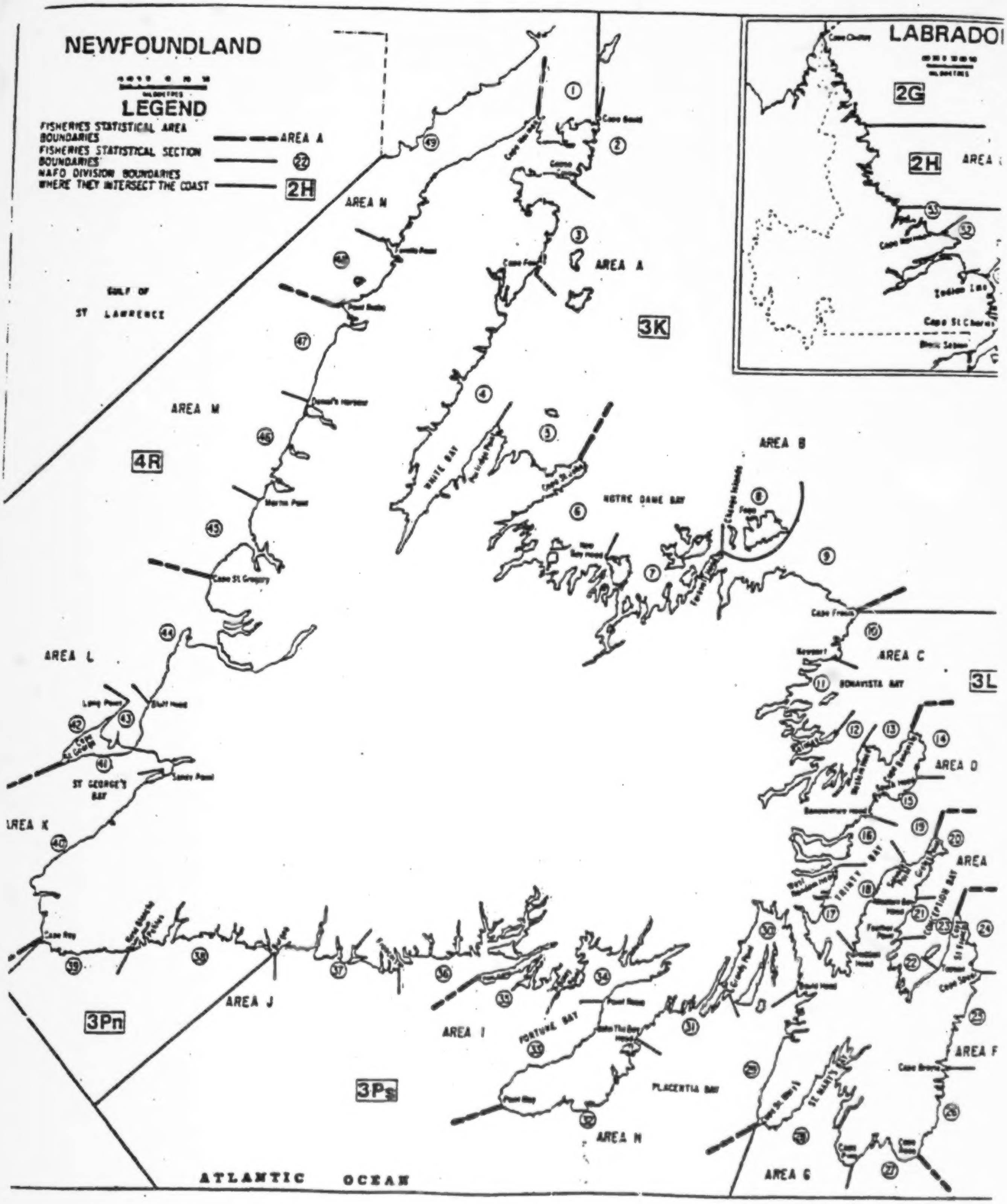
NEWFOUNDLAND
LEGEND
FISHERIES STATISTICAL AREA BOUNDARIES
AREA A
FISHERIES STATISTICAL SECTION BOUNDARIES
22
NAFO DIVISION BOUNDARIES WHERE THEY INTERSECT THE COAST
2H
LABRADO
2G
2H
GULF OF ST LAWRENCE
AREA M
AREA A
3K
4R
AREA B
NOTRE DAME BAY
WHITE BAY
AREA L
AREA C
BONAVISTA BAY
3L
AREA D
ST GEORGE'S BAY
AREA K
TRINITY BAY
CONCEPTION BAY
AREA
AREA J
3Pn
AREA I
FORTUNE BAY
3Ps
PLACENTIA BAY
AREA H
ST MARY'S BAY
AREA G
AREA F
ATLANTIC OCEAN
Cape Bauld
Cape Freels
Cape Race
Cape St Gregory
Cape Ray
Point Riche
Bonavista
Cape Spear
Point May

Fig. 1. Statistical areas (A=White Bay, B=Notre Dame Bay, C=Bonavista Bay, D=Trinity Bay, E=Conception Bay, F=Southern Shore, G=St. Mary's and Trepassey Bays) and sections (numeric) for Newfoundland.

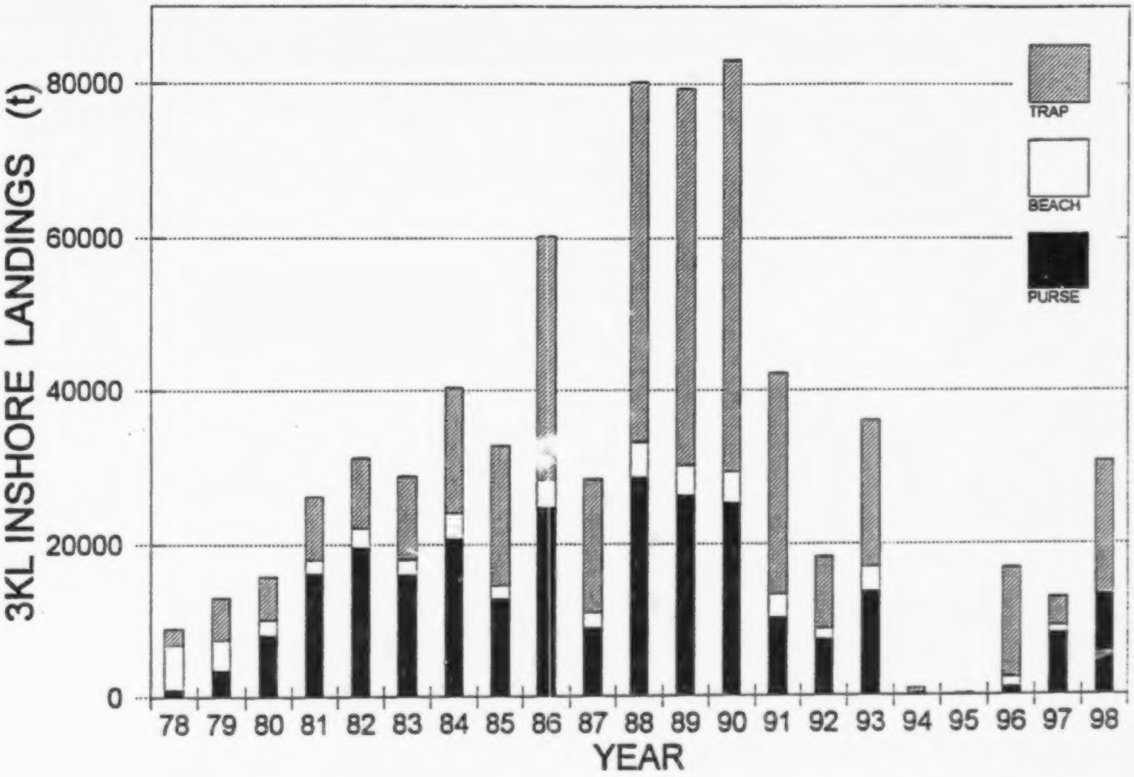

Fig. 2. Inshore capelin landings (t) in Div. 3KL.

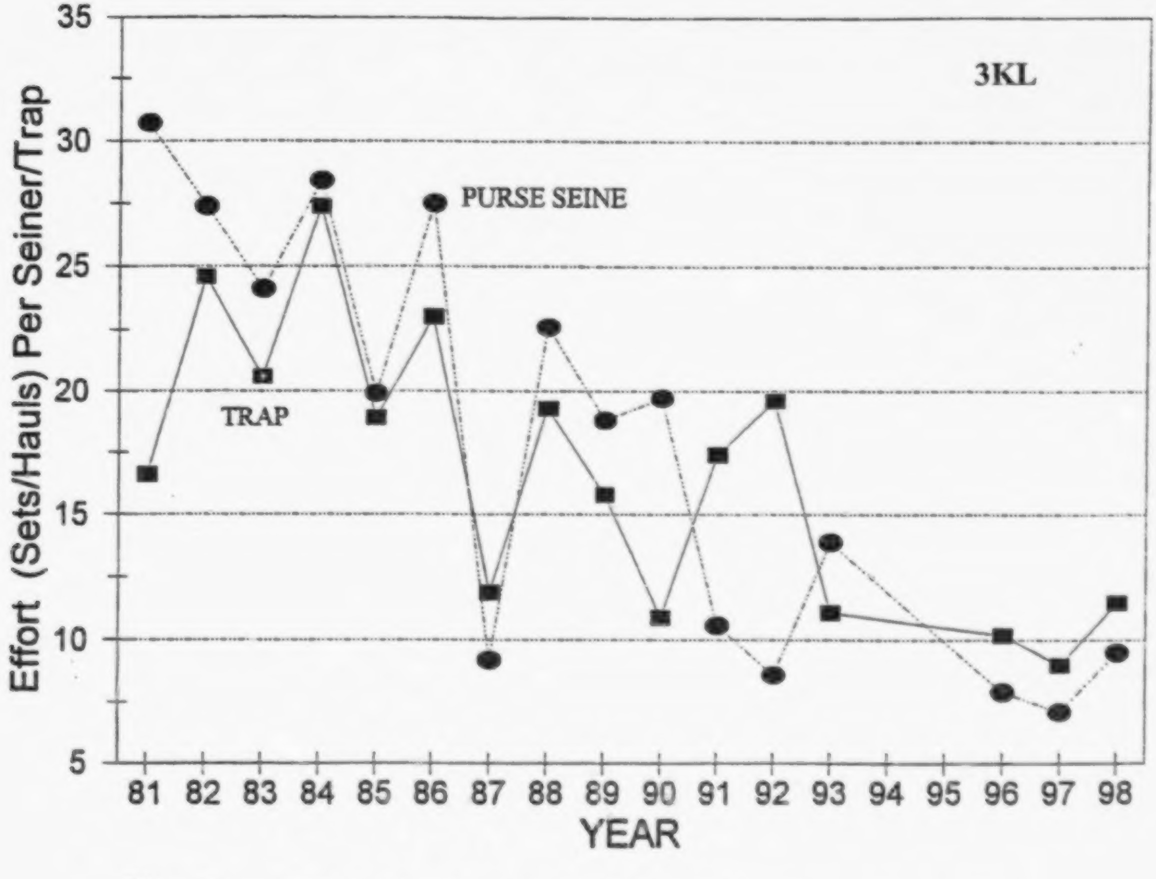

Fig. 3. Trends in average fishing effort for trap hauls (square) and purse seine sets (circle).

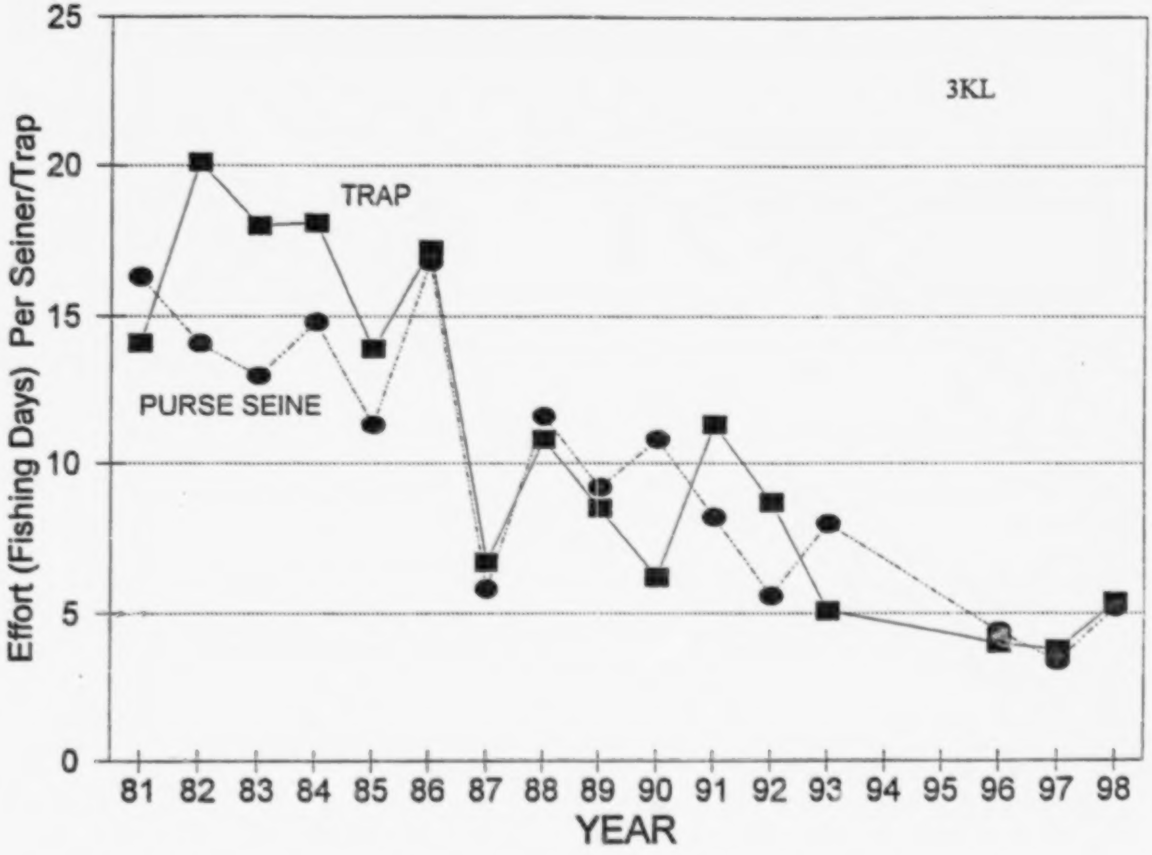

Fig. 4. Trends in average fishing effort for trap fishing days (square) and purse seine searching days (circle).

Results of the 1998 Aerial Survey of Capelin (Mallotus villosus) Schools

by

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Introduction

Area estimates of capelin (Mallotus villosus) schools conducted since 1982 have been used as an index of inshore abundance of mature capelin in NAFO Div. 3L (eg. Nakashima 1996). From 1982 to 1989 school areas were measured from aerial photographs (Nakashima 1990). From 1990 to 1996 school areas were estimated from digital imagery data collected with the Compact Airborne Spectrographic Imager (CASI) (Borstad et al. 1992, Nakashima 1997). In 1997-98 imagery was collected using a video camera. This report presents the results of the 1998 capelin aerial survey.

Materials and Methods

Instrument Operation

A SONY CCD-TR500 video camera was used to collect the imagery. The video camera is equiped with a 10x power zoom lens with f=5.4 to 54 mm. The position of the zoom lens was fixed before the camera was mounted inside the aircraft. A nine-inch portable TV was used to monitor the data as it was being recorded on hi8 tape. In many cases viewing schools on videotape was a better means of identification and interpretation than examining still digital images. The movement and/or changing shape of schools was a useful way to confirm the presence of fish schools.

Area Calibration

Three fixed objects were identified at widely dispersed locations along the two transects. The surface area of the three targets was measured (219, 847 and 1340 m^2) and for every flight at least one target was recorded at the video camera settings and altitudes flown to collect that flight's data.

Survey Method

Particulars of previous aerial surveys including aircraft type, equipment used, survey time, and altitudes flown are listed in Table 1. The optimal altitude for video surveys was 610 m (3000') which was largely governed by the resolution of the videocamera. Flights were limited to early morning and early evening hours similar to conditions imposed by aerial photography. At this altitude maintaining a flight line was more problematic on poor weather days due to turbulence and to local fog conditions. The survey covered two transects as often as possible; the inside of Trinity Bay from Masters Head to Hopeall Head and the inside of Conception Bay from Bryant's Cove to Portugal Cove (Fig. 1). The survey is limited to the inner portions of two bays, covering only a small portion of the coastal habitat occupied by mature capelin schools.

Similar to aerial photography and CASI surveys, an experienced observer identified potential schools along each transect. If there was any doubt as to the presence or absence of a school imagery was collected and examined later. If the schools seen visually by the observer were not observed on the monitor then the line was rerun. The altitude and location were recorded directly onto the videotape via a microphone linked to the intercom system of the aircraft and also written on field sheets.

Analytical Methods

Video data were digitized and transferred to a PC-based image processor for classification and analysis as PCI image files. All potential schools on video tape were identified by the field observer and imaging operator/analyst. The ability to resolve schools fron the background was not as clear as with CASI imagery. With the CASI the bands used to collect imagery can be programmed according to local conditions (eg. Borstad et al. 1992, Nakashima 1997). This was not possible with the commercial video camera. When this problem arose it was overcome by manually tracing the school perimeters. Some electrical interference appeared as 'striping' on some images which disrupted the automatic mode of area calculation. This was corrected in a similar manner.

The same algorithm used to estimate school areas from CASI digital survey data was used to estimate the number of pixels per school on digitized video imagery. Pixel numbers per school were converted to area taking into account pixel size estimated from the calibration sites and altitudes flown. For each transect flown, the mean and median surface areas of capelin schools, the total number of schools, and the total surface area of all schools observed along a transect were estimated.

The school surface area index for each year per transect was estimated by summing the highest total school surface area observed on each transect. I assumed that the peak in school surface area was indicative of inshore abundance for each transect for that year (Nakashima 1985). Survey times reported in Table 1 are the total flying hours and best estimates of the actual time spent per transect are in Tables 2 and 3.

Aerial/Acoustic Experiment

Approximately 7 hours spread out over 5 days were used to collect aerial/acoustic data of schools in the Bellevue-Chance Cove area. Using hand held marine VHF units the aircraft and acoustic vessel coordinated runs over the same capelin schools. In some instances multiple estimates of surface area were made of the same school.

Results and Discussion

In 1998, the aerial survey provided frequent coverage of Conception Bay and Trinity Bay. Complete coverage in Trinity Bay occurred eight times (Table 2) and six times in Conception Bay (Table 3). The total number of hours flown in 1998 was comparable to 1996 and less than in 1997. The less frequent coverage in 1998 can be attributed to poorer flying conditions,low amounts of capelin observed, especially in Conception Bay, and fewer survey days. Eleven days (June 28-29, July 1-3, 5-6, 10-12, 18) were not flown because of poor weather or rough sea conditions.

In Trinity Bay the highest school area estimate was observed on July 8 which was earlier than the last three years (Table 2). The time is about 14 days before the major period (July 22-Aug. 1) of egg deposition on Bellevue Beach in 1998(Fig. 2) (Nakashima and Slaney 1999). In Conception Bay the highest total school area was observed on July 14, the same day as in 1997 (Table 3). For daily estimates prior to 1991 see Nakashima (1995). The peak estimate in Trinity Bay was higher than the long-term geometric mean of 225,516 and for Conception Bay the 1997 estimate of the inside transect was lower than the long-term geometric mean of 153,066 m^2 (Table 4, Fig. 3). Both exclude the 1991 and 1998 estimates.

Several assumptions are required when using this methodology. Schools can only be detected close to shore in shallow water. Schools in deep water remain unobserved from the air. By surveying frequently during the spawning season I assume that all fish will eventually be detected as they move closer to beaches to spawn. Even though all schools may be recorded and measured, by choosing a single estimate of total school area per bay I assume all schools arrive at the same time as a single spawning peak. This is not true (eg. Nakashima et al. 1998).

Using school area as a relative abundance index assumes density/abundance of a school is related to its surface area. Misund et al. (1992) have shown that herring, sprat, and saithe biomasses are correlated to school area and to school volume. Multiple runs over the same school tended to yield consistent estimates of school area for a few schools in 1997 (Nakashima 1998). Acoustic/aerial estimates were made of more capelin schools in 1998. Further experients are planned to define the nature of the area vs volume relationship for spawning aggregations of capelin.

Acknowledgments

Special thanks to Gene Ploughman of Thorburn Aviation for providing the Cessna 185 at short notice and outfitting it for the video camera setup. Jed Samson, the pilot, was invaluable in completing the survey and getting so much accomplished. Digitization and school area measurements were conducted by Borstad Associates Ltd., Sidney, B.C. M. Y. Farrell assisted in the preparation of the manuscript.

References

Borstad, G. A., D. A. Hill, R. C. Kerr, and B. Nakashima. 1992. Direct digital remote sensing of herring schools. Int. J. Rem. Sensing 13: 2191-2198.

Misund, O. A., A. Aglen, A. K. Beltestad, and J. Dalen. 1992. Relationship between the geometric dimensions and biomass of schools. ICES J. Mar. Sci. 49: 305-315.

Nakashima, B. S. 1985. The design and application of aerial surveys to estimate inshore distribution and relative abundance of capelin. NAFO SCR Doc. 85/84, Ser. No. N1058. 11 p.

1990. Capelin school surface area index for NAFO Div. 3L during the 1989 spawning season. NAFO SCR Doc. 90/59, Ser. No. N1780. 6 p.

1998. Results of the 1997 aerial survey of capelin (*Mallotus villosus*) schools. pp. 50-61. *In*: Anon. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 98/63.

Nakashima, B. S. and B. W. Slaney. 1999. Spawning and early life history from Bellevue Beach in 1998. pp. . *In*: Anon. DFO Atl. Fish. Res. Doc. 99/.

Table 1. Summary of aerial surveys.

Year	Aircraft	Camera	Survey period	Altitude (m)	Flight time hrs)
1982	Piper Aztec	RC 10	Jun 18-Jul 5	150-160	?
1983	Aero-Commander RC 10	Wild	Jun 19-Jul 9	460	25.9
1984	Cessna 310 RC 10	Wild	Jun 17-Jul 7	460	38.5
1985	Aero-Commander 500 B	Wild RC 10	Jun 18-Jul 3	290-610	28.6
1986	Aero-Commander 500 B	Wild RC 10	Jun 19-Jul 5	380-580	13.4
1987	Piper Aztec RMK	Zeiss	Jun 16-Jul 3	460	37.0
1988	Piper Navajo Piper Aztec	Zeiss RMK	Jun 15-Jul 5	305-490	33.0
1989	Piper Navajo RMK	Zeiss	Jun 16-27 Jun 30-Jul 4	435-730	26.0
1990	Piper Aztec RMK CASI	Zeiss	Jun 17-Jul 6	570-1260	27.0
1991	Piper Navajo	CASI	Jun 21-25 Jul 3-17	1220	27.3
1992	Cessna 185	CASI	Jun 21-Jul 14	275-1280	34.6
1993	De Havilland Beaver	CASI	Jun 30-Jul 16 Jul 19-22 Jul 26-28	365-1220	46.2
1994	De Havilland Beaver	CASI	Jul 2, 7-19 Jul 24-27 Aug 2-4	1220	43.8
1995	De Havilland Beaver	CASI	Jul 5-21, Jul 27-29	915-1340	42.4
1996	de Havilland Beaver	CASI	Jun 25-Jul 9, Jul 13-16	1060-1260	22.6
1997	Cessna 185	SONY CCD-TR500 HANDYCAM	Jun 29-Jul 24	610-975	41.7
1998	Cessna 185	SONY CCD-TR500	Jun 28-Jul 18	455-970	22.6

Table 2. Schooling data for the inside part of Trinity Bay from Masters Head to Hopeall.

Date		No. of schools	Surface total area (m^2)	School size (m^2)			Survey time (hr)
				Mean	SD	Median	
1991	Jun 23	0	0				1.6
	Jun 24	0	0				1.1
	Jul 5	139	170681	1228	1827	535	2.5
	Jul 14	54	64598	1196	1894	567	1.4
	Jul 16	33	93680	2839	5562	800	1.3
1992	Jun 25	29	40836	1408	1591	1078	1.4
	Jun 29	71	97424	1372	1510	679	1.4
	Jul 6	70	97565	1394	4273	267	2.3
	Jul 8	124	173219	1397	3862	370	2.7
	Jul 13	50	67889	1358	4008	263	1.7
1993	Jul 3	27	CASI data unavailable				1.5
	Jul 12	31	30502	1006	1747[a]	515	1.3
	Jul 14	14	58786	4199	2847	3976	1.1
	Jul 21	22	9760	451	611[a]	260	0.9
1994	Jul 2	0	0				0.3
	Jul 7	14	4311	308	408	220	1.1
	Jul 9	39	65179	1671	2081	846	1.6
	Jul 13	79	522964	6620	18249	577	1.8
	Jul 15	77	539207	7003	24606	706	1.6
	Jul 17	66	377255	5716	18303	1221	1.5
	Jul 19	57	296029	5193	19751	511	1.6
	Aug 2	9	16240	1804	1577	1115	1.0
1995	Jul 8		Transect coverage incomplete				1.0
	Jul 11	39	80225	2057	2575	1045	2.4
	Jul 13	73	(150198)[b]	2058	4700	503	2.7
	Jul 15	184	330010	1794	4751	514	2.5
	Jul 18	59	62737	1063	2955	318	1.1
	Jul 29	8	4460	558	444	492	1.0
1996	Jun 25	28	CASI unavailable				0.8
	Jul 8	119	478888	4024	14210	1000	2.0
	Jul 13	109	562977	5165	11268	1519	2.3
	Jul 15	50	98292	1966	2230	1382	2.8
1997	Jul 6	71	93393	1315	2398	424	1.4
	Jul 7	97	213060	2196	8131	388	1.1
	Jul 8	118	309246	2621	10044	313	1.8
	Jul 10	68	234180	3444	9862	625	1.4
	Jul 12	91	383255	4212	16694	484	1.3
	Jul 13/14	84	384610	4637	9026	1004	1.6
	Jul 17	88	310544	3529	16242	487	1.7
	Jul 19	39	165912	4254	4197	2853	1.0
	Jul 22	73	119727	1640	2611	713	1.3
1998	Jun 30	9	2069	230	224	128	1.3
	Jul 4	86	151603	1763	2135	778	1.6
	Jul 7	56	201565	3599	12587	692	1.5
	Jul 8	82	310569	3787	17254	512	1.2
	Jul 9	52	142609	2742	9735	796	1.5
	Jul 13	117	278876	2384	6745	573	2.4
	Jul 15	50	83342	1667	2249	631	2.3
	Jul 16	43	102412	2382	7165	468	1.8

[a] calculation excludes capelin in traps; [b] underestimate due to corrupted data files

Table 3. Schooling data for the inside of Conception Bay from Harbour Grace Islands to Portugal Cove.

			Surface	School size (m^2)			
	Date	No. of schools	total area (m^2)	Mean	SD	Median	Survey time (hr)
1991	Jul 8		Few schools observed - no CASI data				1.1
	Jul 11	56	15577	278	359	124	1.2
	Jul 17	8	8453	1057	531	875	1.1
1992	Jun 24	8	4772	597	328	468	0.9
	Jun 27	7	11726	1675	3478	133	0.4
	Jul 5	12	24263	2708	2880	2143	1.1
	Jul 6	23	10775	468	620	272	1.7
	Jul 9	30	45748	1525	1865	792	1.3
	Jul 13	63	148629	2359	3294	981	1.0
	Jul 14	143	350988	2454	6098	751	2.6
1993	Jul 2	16	CASI data unavailable				1.9
	Jul 4	45	CASI data unavailable				2.3
	Jul 11	60	102645	1867	4904[a]	440	2.0
	Jul 13	53	44184	910	1247[a]	455	1.7
	Jul 15	18	9670	551	681[a]	323	1.7
	Jul 20	73	69246	984	1357[a]	385	2.5
	Jul 21	72	98938	1390	3678	309	1.9
	Jul 27	69	198968	2884	5960	587	1.6
	Jul 28	35	41844	1196	1521	546	1.2
1994	Jul 2	5	CASI data unavailable				0.5
	Jul 7	9	11368	1263	1614	378	1.6
	Jul 9-10	16	79949	4997	10291	1609	1.8
	Jul 12-13	67	98926	1476	2607	333	1.7
	Jul 14	13	17110	1316	1624	416	1.3
	Jul 15	8	8678	1085	1089	868	0.7
	Jul 16	23	40575	1764	4753	576	1.0
	Jul 18	35	61500	1757	2294	1176	1.6
	Jul 26	0	0				0.9
	Aug 3	0	0				
1995	Jul 5	18	12242	680	813	337	1.1
	Jul 8	47	180070	3831	8506	1051	2.9
	Jul 12	5	717	143	59	120	1.5
	Jul 15	13	56285	4330	5147	1389	1.5
	Jul 21	75	51352	685	1161	284	2.8
	Jul 28	65	64918	999	2539	272	1.8
1996	Jun 25	12	CASI unavailable				0.8
	Jul 8-9	120	196509	1605	2829[a]	742	1.7
	Jul 13	8	12533	1567	1368	1002	1.6
1997	Jul 3	1	772	772	-	772	1.3
	Jul 7	0	0				1.0
	Jul 9	4	1572	393	204	429	1.1
	Jul 12	69	134150	1944	2470	898	1.5
	Jul 14	93	159485	1715	3298	341	1.7
	Jul 18	56	58898	1052	1888	518	1.7
	Jul 22	11	28296	2572	2718	1250	1.3
1998	Jun 30	1	1590	1590		1590	1.2
	Jul 4	5	5486	1097	1003	537	1.5
	Jul 8	13	5928	456	511	271	1.5
	Jul 9	25	22575	903	1084	563	1.4
	Jul 14	52	109021	2097	6152	973	1.7
	Jul 17	25	47154	1886	3409	801	1.7

[a] calculation excludes capelin in traps

Table 4. School surface area (m^2) estimates for Trinity Bay and Conception Bay.

Year	Trinity Bay	Inner Conception Bay	Outer Conception Bay
1982	62,397	151,214	6,577
1983	199,373	97,595	51,838
1984	43,245	63,891	65,956
1985	195,659	43,228	69,166
1986	95,898	31,574	132,455
1987	399,026	205,846	184,307
1988	112,863	201,642	87,534
1989	84,349	187,311	266,878
1990	141,122	128,743	88,759
1991	(170,681)[a]	(15,577)[a]	(6,374)[a]
1992	173,219	350,988	225,838
1993	58,786[b]	198,968	77,202
1994	539,207	98,926	28,339
1995	330,010	180,070	126,670
1996	562,977	196,509	77,650
1997	384,610	159,485	-
1998	310,569	109,021	-

[a] The survey in 1991 was over before inshore spawning had begun.
[b] Underestimate-spawning in August was missed.

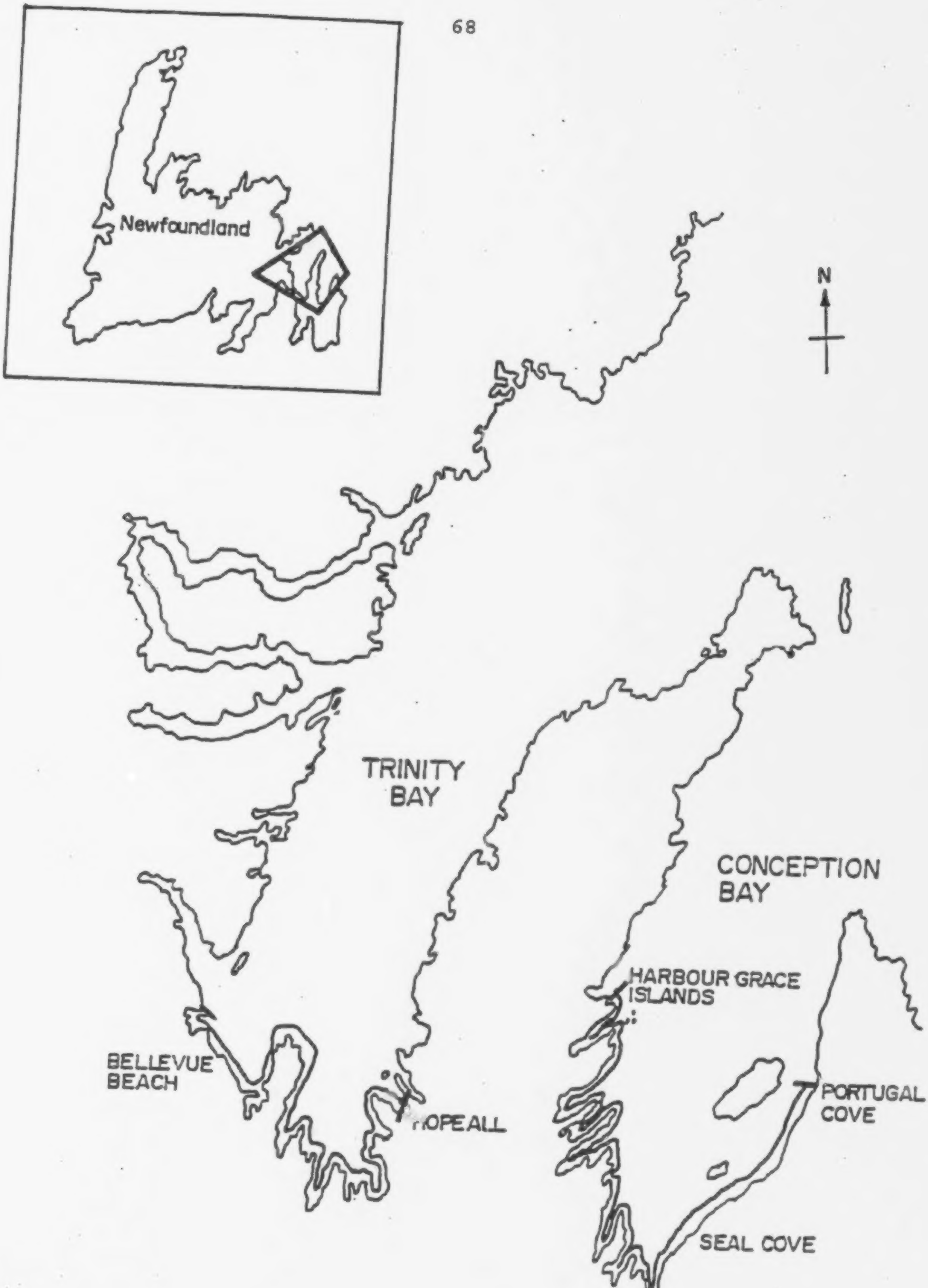
Newfoundland
N
TRINITY BAY
CONCEPTION BAY
HARBOUR GRACE ISLANDS
BELLEVUE BEACH
HOPEALL
PORTUGAL COVE
SEAL COVE
HOLYROOD

Fig. 1. Transects flown during the aerial survey.

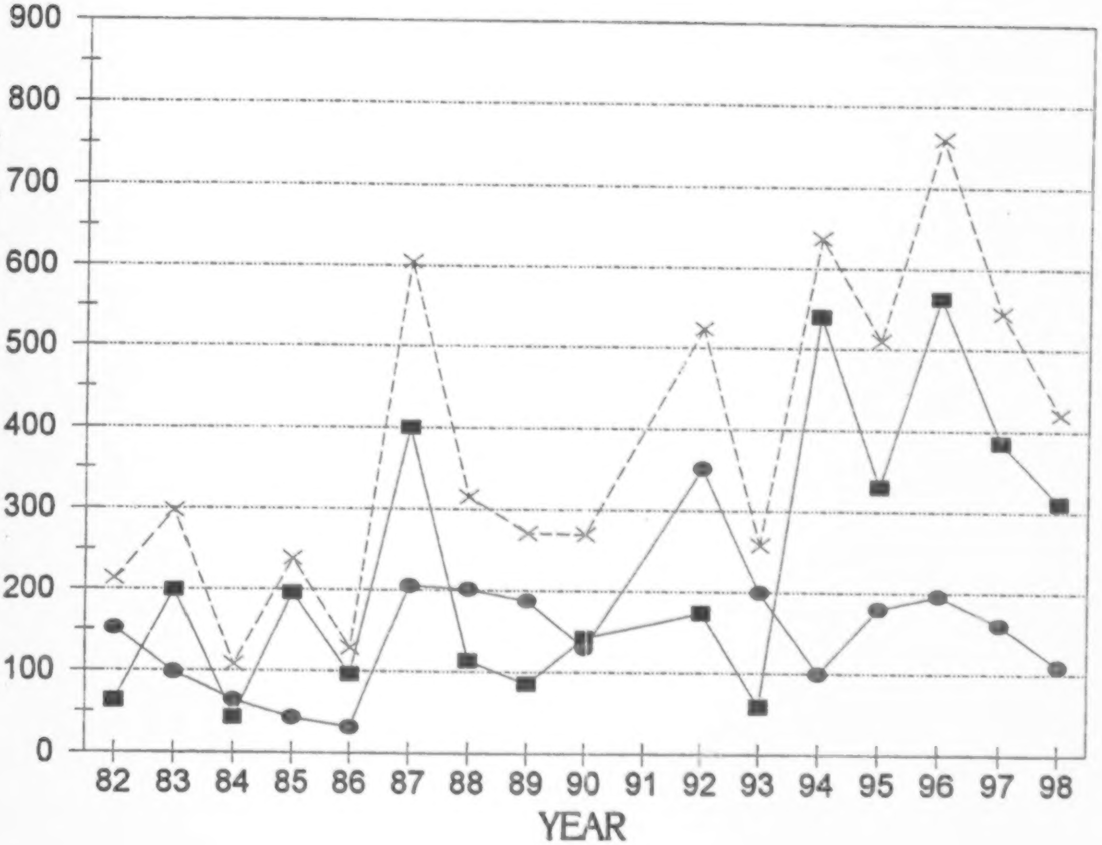

Fig. 3. Annual trends in school surface area for Trinity Bay (squares), Conception Bay (circles), and the two transects combined (X).

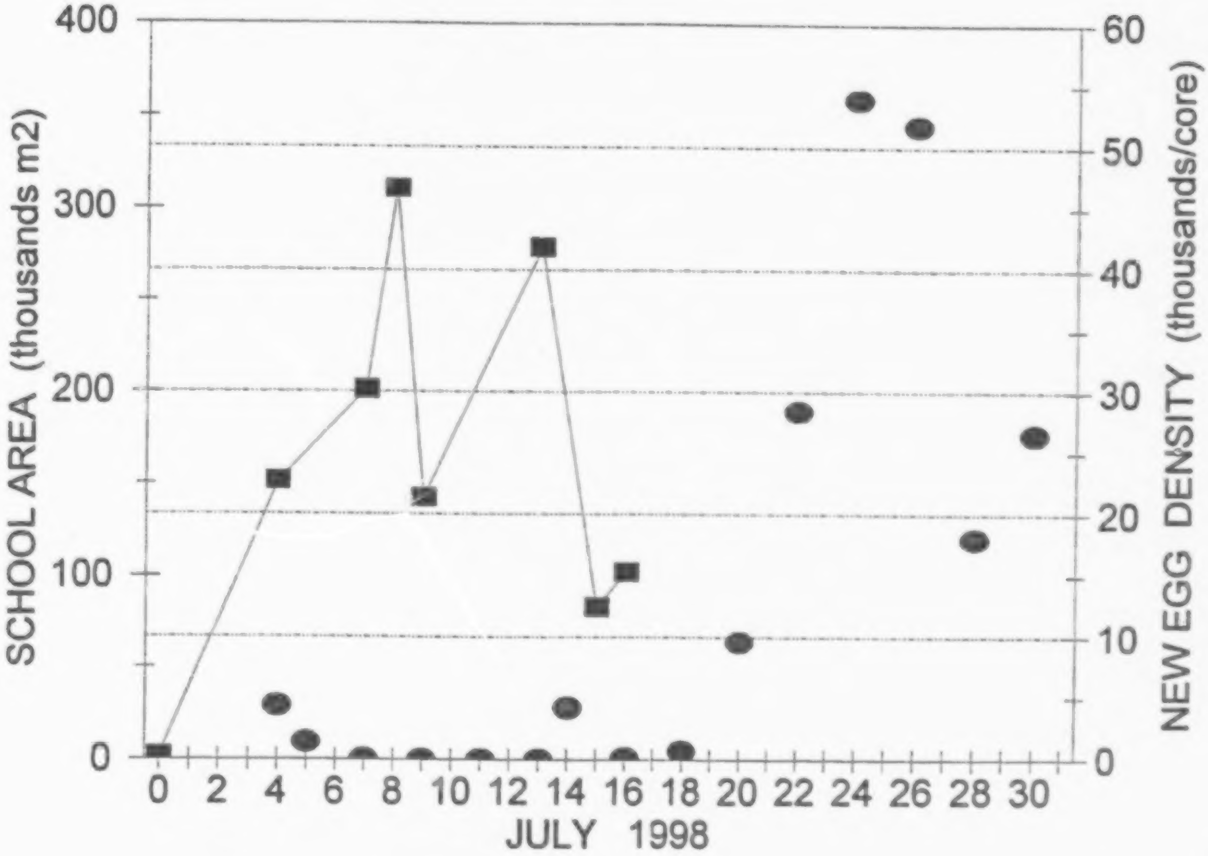

Fig. 2. Daily pattern of school areas in Trinity Bay (squares) and egg deposition at Bellevue Beach (circles) in July 1998.

Chapter 4

Spawning and Early Development of Capelin (Mallotus villosus) from Bellevue Beach, Trinity Bay in 1998

by

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Introduction

In 1990 we began to monitor spawning times, egg deposition and development, larval emergence and various environmental variables (eg. sunlight hours, wind direction and speed, air temperature, water temperature, precipitation, beach sediment temperatures, beach disturbance) on two capelin spawning beaches located at Arnold's Cove in Div. 3Ps and at Bellevue Beach in Div. 3L (Fig. 1). The number of sites was expanded in 1991 to include five additional beaches at Chapels Cove, Eastport, Cape Freels, Twillingate, and Hampden in Div. 3KL (Fig. 1). In 1995 Chapels Cove and Bellevue Beach were sampled. Information from these other sites can be found in Nakashima and Winters (1997). Since 1996 Bellevue Beach has been the only monitored site. In this report we present information on age, length, and weight of spawners, spawning times, egg densities, and pre-emergent and emergent larval estimates from Bellevue Beach in Div. 3L. The approach differs from past reports that presented data from all sites monitored in Div. 3KL (e.g. Nakashima et al 1998).

Materials and Methods

Adult Samples

Random samples of 25 males and 25 females were collected whenever significant spawning had taken place. Random samples were also collected from a capelin trap located nearby at Rantem. Fish were measured for length and weight and otoliths removed for age determination.

Egg and Larval Sampling

During low tide conditions egg samples in beach sediments were collected once every 48 hrs until eggs were no longer on the beach (<500 eggs per sample) and the numbers of pre-emergent larvae had declined. Nine samples subdivided into three samples per tidal zone (low tide, mid tide, high tide) were collected each time. A steel sediment corer (6.5 cm internal diameter) was used to extract each sample as described in Nakashima and Slaney (1993). Samples were preserved in 4% formalin and seawater solution buffered with sodium borate. To separate eggs from sediments, samples were immersed in 2% KOH solution for 24 hrs. To estimate pre-emergent larvae in beach cores larvae were sorted from eggs and counted. To estimate egg abundance, eggs were counted by subsampling with a whirling vessel (Nakashima 1987).

At each sampling site at least 50 eggs were placed in Stockard's Solution (Bonnet 1939) to fix and clear the eggs. Stages I-II (eggs from fertilization to the formation of the blastula) accounts for egg development up to the first 36 hrs at 7.2°C (Fridgeirsson 1976).

Newly emerging larvae were collected in the intertidal zone at high tide conditions generally twice a day. A 165 um plankton net was towed for 40 m parallel to the beach, rinsed, and the contents preserved in 4% formalin and seawater solution buffered with sodium borate. Two tows were conducted each time but only one sample was counted. Larvae were categorized as in 'good' or 'bad' condition based on visual inspection. Larval density was expressed as larvae per m3.

Trapezoidal Integration

Total annual production of eggs and pre-emergent larvae were estimated by interpolating between point estimates applying trapezoidal integration. The seasonal estimate is:

$$\sum (t_n - t_{n-1}) \tfrac{1}{2} [X(t_n) + X(t_{n-1})]$$

where t is the julian day, n is the number of sampling days, and X(t) is the number of eggs or larvae on day t.

Egg and Larval Densities

The ratio of Stage I-II eggs to total eggs in the Stockard's sample was used to estimate the number of Stage I-II eggs occurring in each beach core sample assuming that these eggs had been deposited recently on the beach. The daily average density of stages I-II eggs in all cores per tidal zone on a given beach was then estimated. An average beach density was assumed to be the mean of the three tidal zones. Total egg density of stages I-II eggs per unit area was estimated using the trapezoidal integration method.

The daily average density of pre-emergent larvae in all cores per tidal zone was estimated. An average density was assumed to be the mean of the three tidal zones. Total pre-emergent larval density was estimated using the trapezoidal integration method, as well.

The daily average density of emergent larvae was assumed to be the mean of the two high tide estimates. Total larval density per m^3 was then estimated using the trapezoidal integration method.

Results and Discussion

Spawner Characteristics

Age compositions of spawning fish from 1990 to 1998 were dominated by age 3 fish in all years except 1992 when age 4's were most abundant (Table 1). Our age composition data show that the 1998 spawning population consisted mainly of the 1995 yearclass (66%) followed by the 1994 yearclass (17%). The proportion of age 2 fish is considerably higher for females than for males. The 1997 yearclass with sexes combined as age 2 represented 14% of the overall mature population spawning in the vicinity of Bellevue Beach (Table 1).

Mean weights and lengths of females and males and the population in general are presented in Table 2.

Spawning Time

The extent and timing of the spawning period in 1998 was similar to 1991 and 1992 and earlier than in 1997 (Table 3). However, most of the eggs had been deposited by July 23 in 1997

(Fig. 3: Nakashima et al 1998) compared to a later time in 1998(Fig. 2).

Egg Density

One major spawning mode was observed in late July (July 21-31) (Fig. 2) with a few small modes on either side. Egg densities on Bellevue Beach were the highest in the series (Table 3). This suggests for this area the mature population spawning on the beach sediment was considerably higher than in 1997.

Pre-emergent Larval Estimates

The majority of pre-emergent larvae observed in beach sediments at Bellevue Beach in 1998 occurred July 31-Aug. 4 and Aug. 12-20 (Fig. 3). The density of pre-emergent larvae was the lowest in the series (Table 3). This implies that the 1998 year class is the weakest one produced at Bellevue Beach in the 1990s.

Emergent Larvae

Emergent larval densities were very low in 1998 with one distinct peak on August 12 at night (Fig. 4). Similar to the pre-emergent larvae the results indicate the 1998 year-class is the weakest in the series and comparable to the 1991 year-class (Table 3).

Summary

The results suggest that there was a high mortality of eggs in Bellevue Beach sediments in 1998 resulting in low densities of pre-emergent larvae. This also affected the potential production of emergent larvae. When evaluating eggs for development staging we noticed a higher proportion of opaque and abnormal eggs in the samples than in recent years.

Acknowledgements

Pelagic Fish Section staff and summer students collected the field data. Core and emergence samples were processed by C. Coady, J. Croft, and A. Powell. Eggs were counted by D. Joy and S. Flynn. R. Clarke, Chance Cove collected capelin samples throughout the spawning season and performed frequent CTD casts. M. Y. Farrell assisted in the preparation of the manuscript.

References

Bonnet, D. D. 1939. Mortality of the cod egg in relation to temperature. Biol. Bull. 76: 428-441.

Fridgeirsson, E. 1976. Observations on spawning behaviour and embryonic development of the Icelandic capelin. Rit. Fiskideildar 5: 1-24.

Nakashima, B. S. 1987. Regional and temporal variations in fecundity of capelin in Newfoundland waters. Trans. Am. Fish. Soc. 116: 864-873.

Nakashima, B. S., and B. W. Slaney. 1993. Capelin (Mallotus villosus) egg deposition on fifteen spawning beaches in Conception Bay, Newfoundland in 1992. DFO Atl. Fish. Res. Doc. 93/7. 11 p.

Nakashima, B. S., and G. H. Winters. 1997. Egg and larval production from Bellevue Beach, Trinity Bay in 1996. pp. 74-83. In: Anon. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 97/29.

Nakashima, B. S., G. H. Winters, and B. W. Slaney. 1998. Spawning, egg densities, and pre-emergent larvae from Bellevue Beach, Trinity Bay in 1997. pp. 62-71. In: Anon. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 98/63.

Table 1. Age composition by numbers for mature capelin from Bellevue Beach, Trinity Bay combined. In 1990 only females were sampled.

Sex	Year	Age					Sample size
		2	3	4	5	6	
M	1991	9.7	40.3	45.0	5.0	0	300
	1992	3.5	30.0	58.0	8.5	0	200
	1993	1.0	68.0	29.0	2.0	0	300
	1994	9.3	56.5	28.8	5.1	0.3	375
	1995	7.3	54.0	27.4	11.0	0.3	328
	1996	4.4	67.6	26.5	1.3	0.3	321
	1997	5.3	48.5	37.7	8.0	0.6	324
	1998	2.0	74.8	20.2	3.0	0	396
F	1990	4.9	49.8	42.1	3.2	0	247
	1991	15.1	45.8	31.5	7.1	0.4	238
	1992	10.0	37.0	44.0	8.5	0.5	200
	1993	11.0	70.0	17.3	1.7	0	300
	1994	17.9	49.9	24.3	7.7	0.3	375
	1995	24.5	55.0	12.7	7.9	0	229
	1996	14.2	61.3	21.8	2.1	0.7	289
	1997	14.5	49.4	26.2	9.3	0.6	324
	1998	26.6	56.1	14.4	3.0	0	369
Combine	1991	12.1	42.8	39.0	6.0	0.2	
	1992	6.8	33.5	51.0	8.5	0.3	
	1993	6.0	69.0	23.2	1.8	0	
	1994	13.6	53.2	26.5	6.4	0.3	
	1995	14.4	54.4	21.4	9.7	0.2	
	1996	9.0	64.6	24.3	1.6	0.5	
	1997	9.9	48.9	31.9	8.6	0.6	
	1998	13.9	65.8	17.4	3.0	0	

Table 2. Mean weights (W in gms) and mean lengths (L in mm) of males, females and sexes combined from samples of spawners collected at Bellevue Beach.

Year	Males		Females		Sample	
	W	L	W	L	W	L
1990	-	-	24.9	160	-	-
1991	31.8	173	20.4	156	26.7	165
1992	25.2	165	17.2	150	21.2	158
1993	27.5	167	17.5	150	22.5	159
1994	26.0	167	18.6	153	22.3	160
1995	24.3	161	14.8	141	20.4	153
1996	28.2	169	18.5	154	23.6	162
1997	24.6	163	18.1	149	21.4	156
1998	25.5	165	16.5	149	21.2	157

Table 3. Annual estimates derived from trapezoidal integration of egg deposition, pre-emergent larvae, and emergent larvae and range of spawning dates for Bellevue Beach, Trinity Bay.

Year	Egg deposition Stages I-II eggs ('000 eggs/core)	Pre-emergent Larvae ('000 larvae/core)	Emergent larvae ('000 larvae/m^3)	Spawning Dates (Julian Day)
1990	92.2	26.2	212.1	175-207
1991	242.2	9.0	60.5	185-234
1992	261.7	18.3	192.5	185-232
1993	337.6	27.1[a]	175.3[b]	182-242
1994	192.5	17.4	109.8	180-217
1995	153.8	20.9	140.1	192-218
1996	243.3	15.2	93.6	178-215
1997	263.5	21.5	-	191-224
1998	452.6	6.2	45.0	183-228

[a] Adjusted to account for sampling stopped before all eggs had hatched. Unadjusted estimate was 17.2.

[b] Adjusted to account for sampling stopped before all larvae had emerged from sediments. Unadjusted estimate was 111.0.

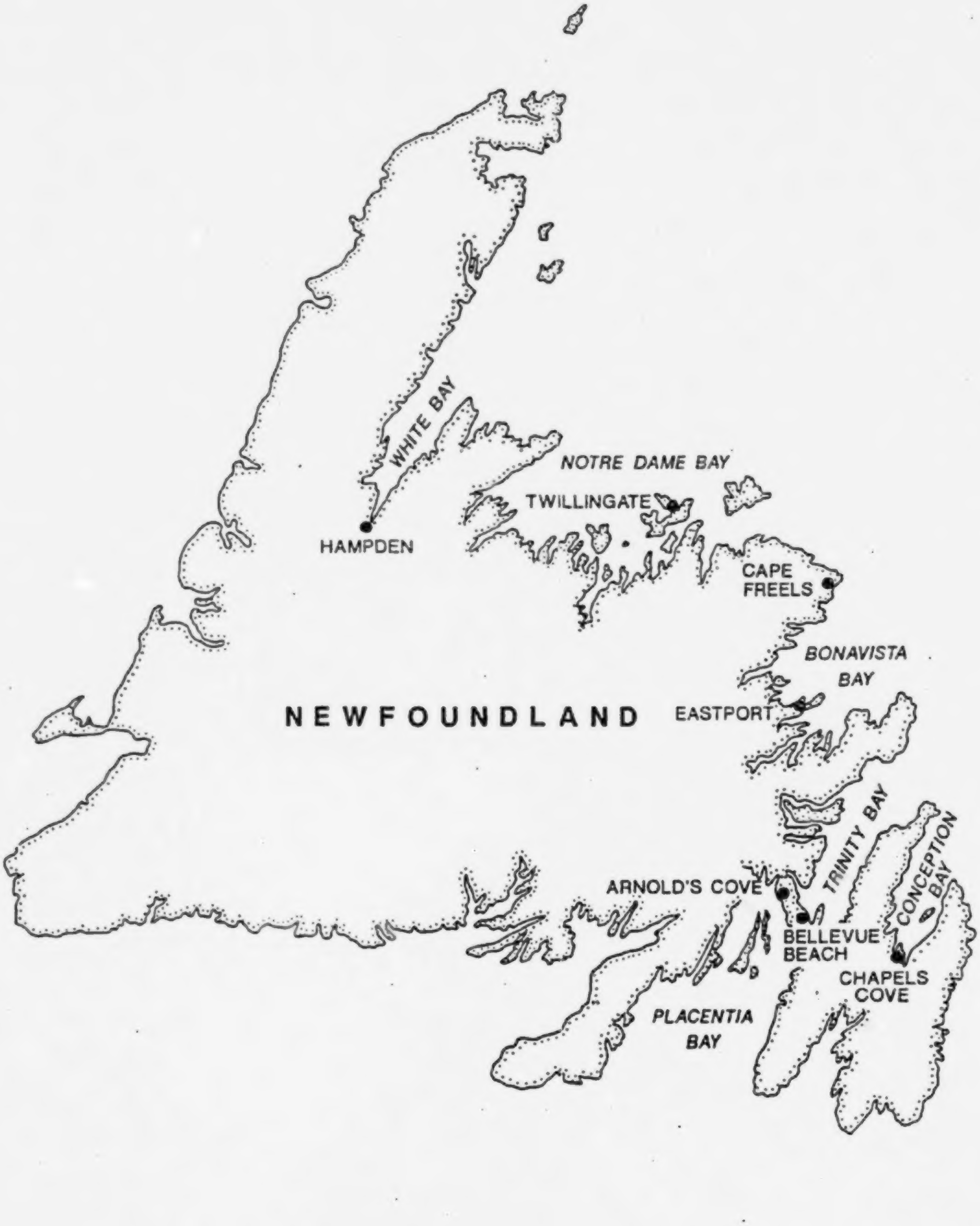
WHITE BAY
NOTRE DAME BAY
TWILLINGATE
HAMPDEN
CAPE FREELS
BONAVISTA BAY
NEWFOUNDLAND
EASTPORT
TRINITY BAY
CONCEPTION BAY
ARNOLD'S COVE
BELLEVUE BEACH
CHAPELS COVE
PLACENTIA BAY

Fig. 1. Sampling sites.

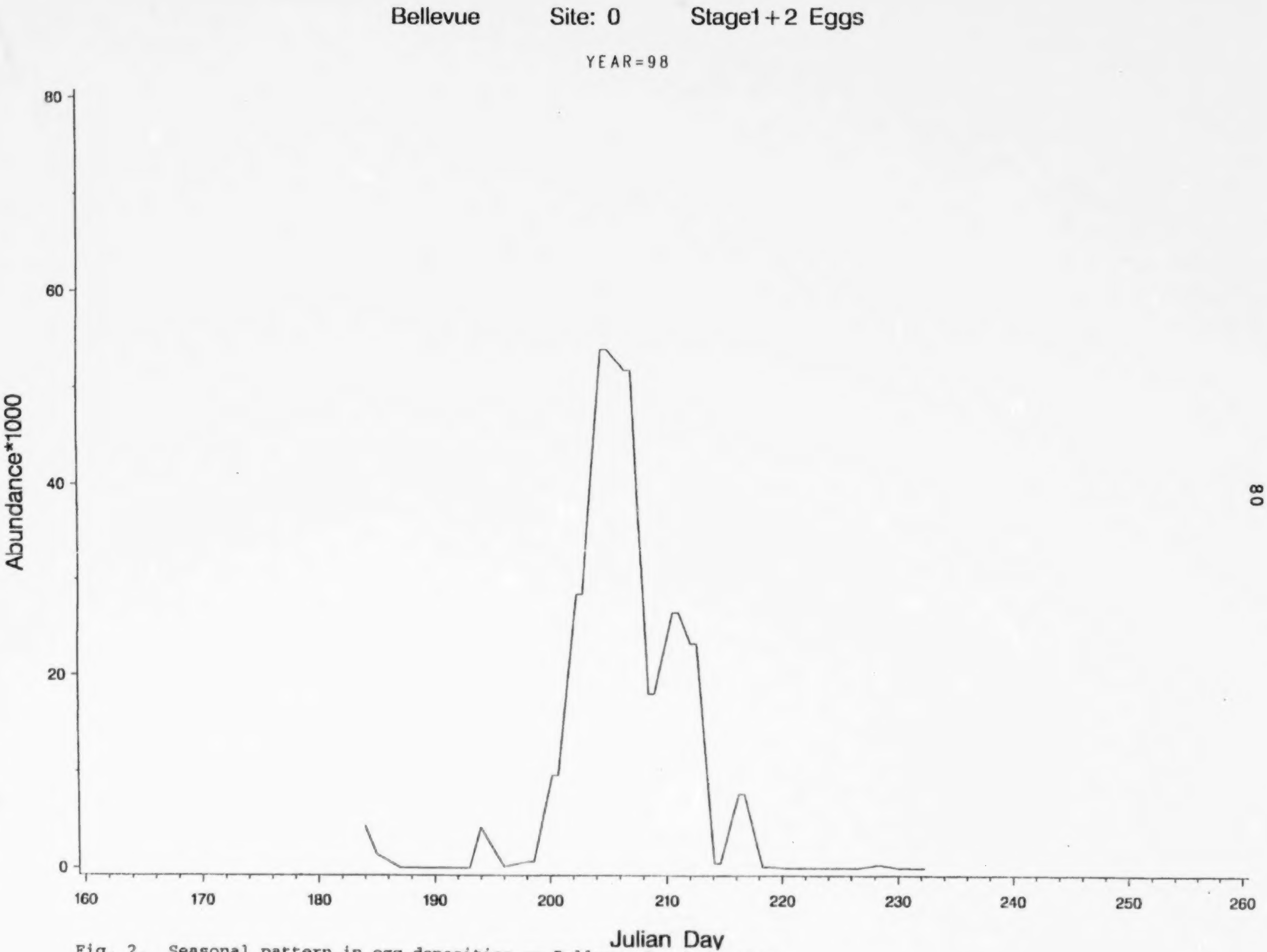

Fig. 2. Seasonal pattern in egg deposition on Bellevue Beach in 1998.

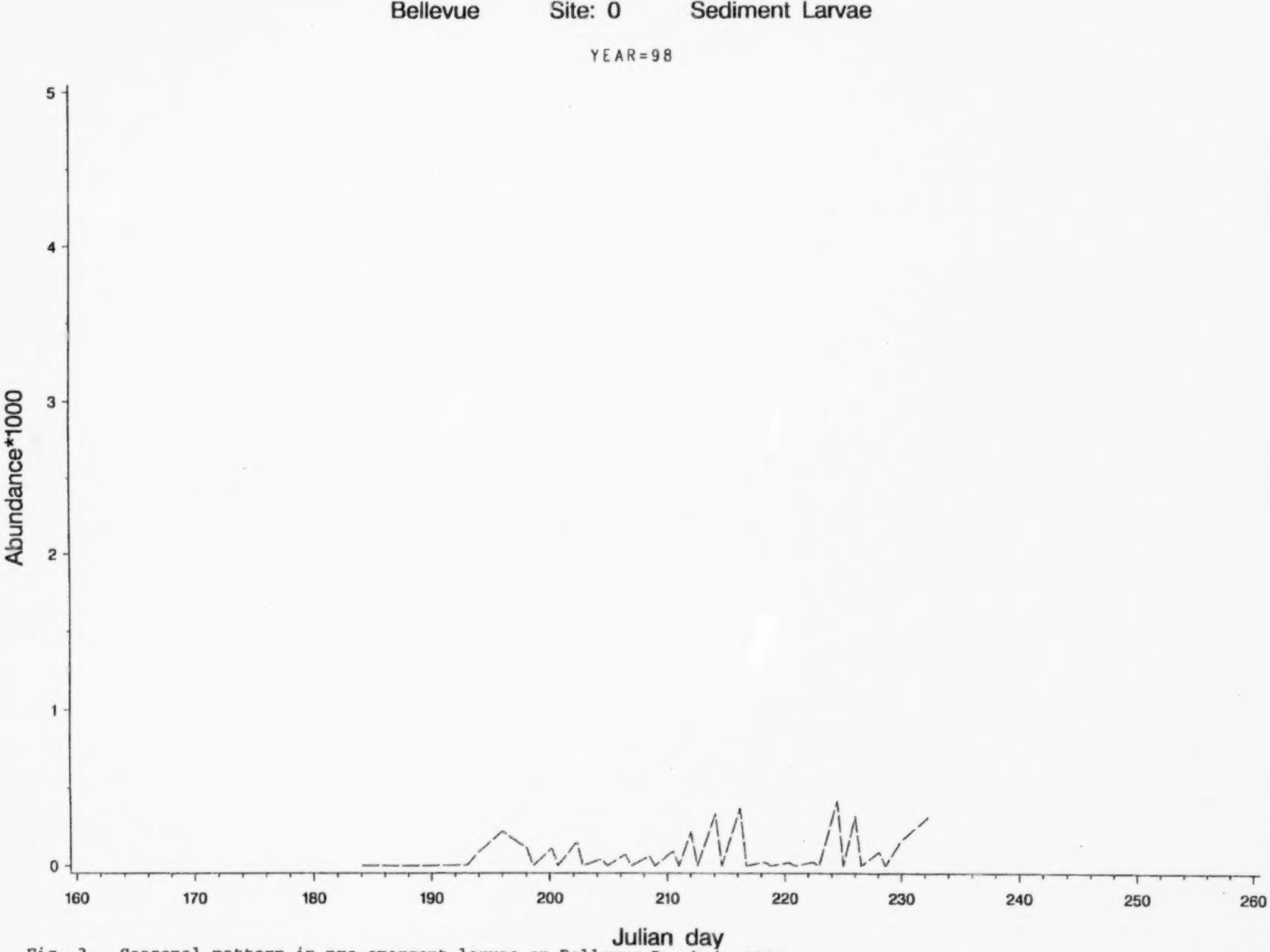

Fig. 3. Seasonal pattern in pre-emergent larvae on Bellevue Beach in 1998.

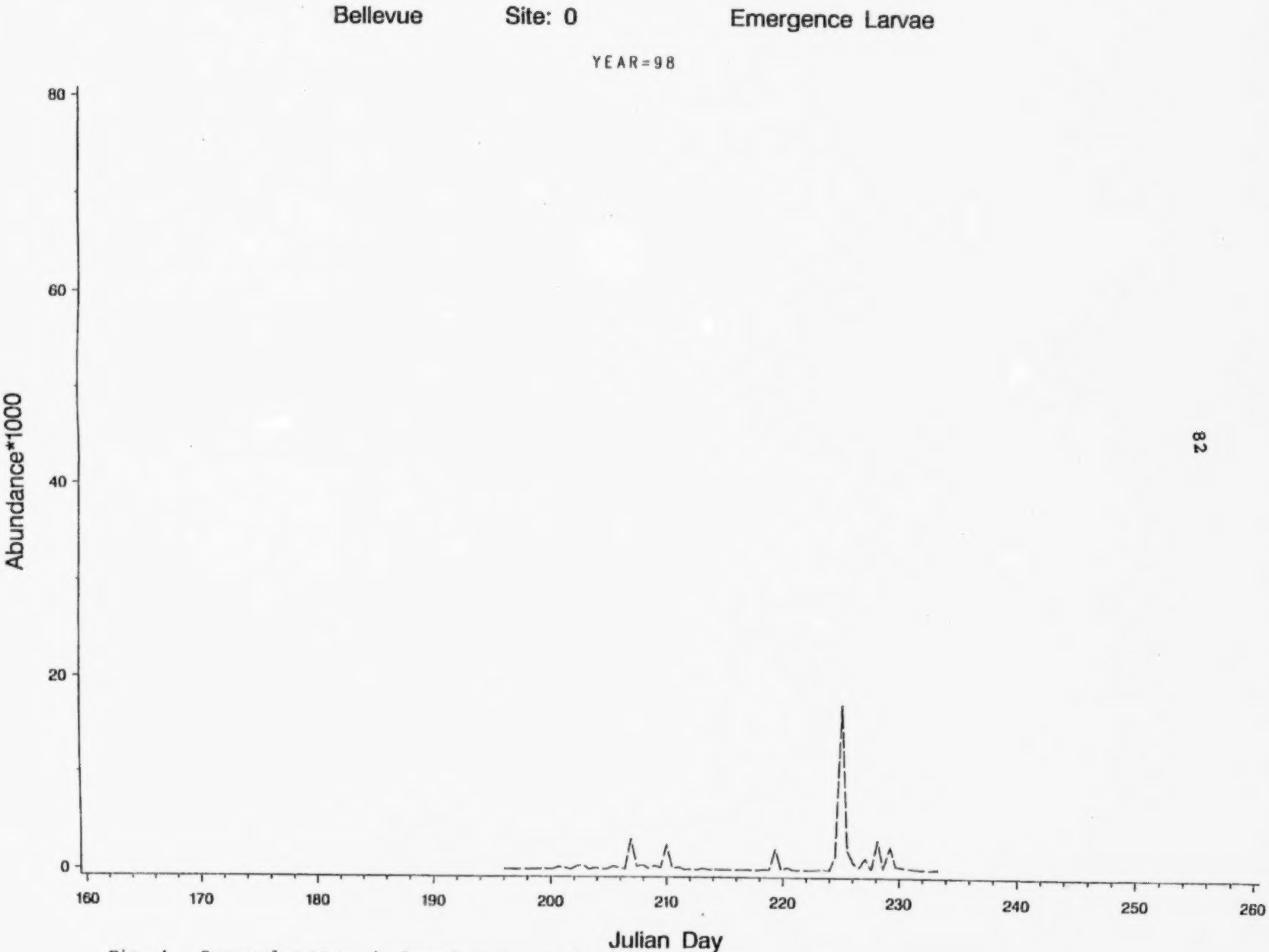

Fig. 4. Seasonal pattern in larval emergence from Bellevue Beach in 1998.

By-catches of capelin during spring and autumn bottom-trawl surveys in Divisions 2J3KL in 1998

by

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Introduction

Capelin (Mallotus villosus) are frequently caught during bottom-trawl surveys directed toward demersal fish off southern Labrador and eastern Newfoundland. The distribution and magnitude of capelin catches from the surveys in Div. 2J, 3K and 3L during the autumns of 1978-97 and the springs of 1972-97 have been compared with geographic coverage by acoustic surveys for capelin to help determine whether coverage by the acoustic surveys has been adequate (Carscadden et al. 1989, Carscadden et al. 1990, Miller and Lilly 1991, Lilly 1992, Lilly and Davis 1993, Lilly 1994a, 1995ab) and to provide supporting data on changes in capelin distribution (Lilly and Davis 1993, Lilly 1994b, 1995c, 1996, 1997, 1998). There has also been interest in exploring the extent to which the frequency of occurrence of capelin in bottom-trawl catches might provide an index of capelin abundance. This chapter provides information on the distribution and frequency of occurrence of capelin during the trawl surveys in spring and autumn 1998. Capelin abundance and biomass, as estimated from areal expansion of the mean catch per tow, are also presented.

Materials and Methods

Surveys in Div. 2J3KL in autumn

Capelin were caught during random-stratified bottom-trawl surveys designed to assess the biomass of demersal fish during October-December 1978-98 (Table 1). All surveys in Div. 2J and 3K in 1978-94 were conducted with the 74 m stern trawler 'Gadus Atlantica'. Surveys in Div. 3L in 1981-83 and 1985-94 were conducted with the 51 m side trawler 'A. T. Cameron' (1981-82) and the sister 50 m stern trawlers 'Wilfred Templeman' (1983, 1985, 1987-94) and 'Alfred Needler' (1986). There were no autumn surveys in Div. 3L in 1978-80 and 1984. The 'Gadus Atlantica', 'Wilfred Templeman' and 'Alfred Needler' deployed an Engel 145 Hi-Lift trawl, whereas the 'A.T. Cameron' deployed a Yankee 41-5 trawl. In all instances, a 29 mm mesh liner was inserted in the codend. Tows were made at 3.5 knots for 30 min at each fishing station, and catches from the few tows of duration other than 30 min were appropriately adjusted. The variability in ships and bottom-trawls (McCallum and Walsh 1997) may have resulted in differences in catching efficiency, but this possibility has not been examined for capelin. Additional details regarding areas and locations of strata, and changes in survey pattern, are provided by Doubleday (1981), Lilly and Davis (1993), Bishop (1994) and Lilly et al. (1998). The most notable change in survey coverage was the addition of depths between 100 and 200 m in northwestern Div. 3K (St. Anthony Shelf and Grey Islands Shelf) in 1984 and subsequent years. Fishing in all Divisions and years was conducted on a 24-h basis.

The survey in autumn 1995 differed from that in previous years in several respects (Brodie 1996). The 'Gadus Atlantica' was replaced by the 63 m stern trawler 'Teleost', the Engel 145 Hi-Lift trawl was replaced with a Campelen 1800 shrimp trawl with rockhopper foot gear, tows were made at 3.0 knots for 15 min instead of 3.5 knots for 30 min, and the 'Wilfred Templeman' fished north of Div. 3L for the first time in the time-series. In 1996 the survey was extended to depths of 1500 m and new strata were added in the inshore (9 strata in Div. 3K and 16 in Div. 3L). The survey in 1997 was similar to that in 1996, except that some of the new inshore strata were modified and one stratum was added. The survey in 1998 was similar to that in 1997.

Surveys in Div. 3LNO in spring

Capelin were caught during random-stratified bottom-trawl surveys of Div. 3LNO during April-June 1971-98, excluding 1983 (Table 2). Surveys were conducted with the 51 m side trawler 'A. T. Cameron' (1971-82) and the sister 50 m stern trawlers 'Wilfred Templeman' (1985-98) and 'Alfred Needler' (1984). The 'A. T. Cameron' deployed a Yankee 41-5 trawl, and the 'Wilfred Templeman' and 'Alfred Needler' deployed an Engel 145 Hi-Lift trawl until 1995. In all instances, a 29 mm mesh liner was inserted in the codend. Tows were made at 3.5 knots for 30 min at each fishing station, and catches from the few tows of duration other than 30 min were appropriately adjusted. No adjustments were made for possible between-vessel differences in catching efficiency. Starting in spring 1996, the Engel 145 Hi-Lift trawl was replaced with the Campelen 1800 shrimp trawl with rockhopper foot gear and tows were made at 3.0 knots for 15 min.

Most surveys in Div. 3L in the 1970's and 1980's were conducted in May (Fig. 1). The 1971 survey was conducted entirely in June, and the 1981 survey was conducted primarily in April. The 1985 survey was part of special seasonal surveying, and was conducted by three consecutive trips of the 'Wilfred Templeman' over a period of 40 d. From the late 1980's to the mid-1990's the median date of fishing shifted from mid-May to mid-June. The 1998 median date of June 22 was the latest in the series.

Distributions

The distribution of capelin is presented in expanding symbol plots, as opposed to contour plots generated from modelling of the catches, in order to provide visual information on the spatial distribution of fishing stations, among-station variability in catch of capelin, and the relationship between capelin catches and bathymetry.

Estimation of frequency of occurrence of capelin

The frequency of occurrence of capelin in the bottom-trawl catches is simply the number of occurrences expressed as a percentage of the number of sets. The number of sets assigned to each stratum was approximately equal to stratum area except during the autumn surveys of 1991-94, when a proportionally higher number of sets was assigned to certain strata in which the variance of the cod catch had been high for some years previous. To adjust for variation in the number of sets per unit area, an adjusted percentage occurrence was calculated as

$$O_{ad} = \frac{\sum_{h=1}^{m} \left(\frac{100(nc_h)}{n_h} \right) A_h}{\sum_{h=1}^{m} A_h}$$

where nc_h is the number of sets in which capelin were caught in stratum h, n_h is the number of sets in stratum h, A_h is the area of stratum h, and m is the number of strata fished.

Estimation of capelin biomass and numbers

The biomass of capelin in each stratum was estimated as

$$W_h = \frac{A_h \sum_{i=1}^{n_h} W_{hi}}{a n_h}$$

where W_{hi} is the weight (kg) of capelin in set i (i = 1, 2, ..., n_h) in stratum h, and a is the area sampled by a standard tow. The biomass in each Division was obtained by summing over strata. Population abundance was estimated in the same way. The abundance of capelin was not estimated for spring surveys in Div. 3L because the number of capelin in the catch was not always recorded, especially in some years in the 1970s.

Results

Capelin in Div. 2J3KL during autumn

Distribution

In Div. 2J3K during the autumn of 1998, capelin were recorded at 66% of the 233 fishing stations conducted at depths of 750 m or less (Table 3). This percentage is the highest since the surveys started in 1978. Catches (median = 2.2 kg; 95th percentile = 46 kg) were similar to those in 1995 and larger than in 1996 and 1997 (Table 3). Large catches occurred on the coastal shelfs off southern Labrador and northeastern Newfoundland and eastward to the western slopes of Belle Isle Bank and Funk Island Bank (Fig. 2). There were also good catches on the northern and northeastern slopes of Grand Bank. All of the large catches in the offshore occurred within the area covered by the acoustic survey in 1994, but the large catches in the inshore would have been shoreward of an acoustic survey, if one had been run using the survey blocks employed in 1994. In general, the distribution in 1998 was similar to that seen in several years during the 1980s, most notably 1986 and 1987 (Lilly 1995c). The distribution had been shifted to the southeastern part of the Northeast Newfoundland Shelf during 1991-96 (Lilly 1995c, 1996, 1997). A hint of a return toward the historic pattern was seen in 1997 (Fig. 3).

In Div. 3L, capelin were recorded at 59% of the 140 stations (Table 4). This is the third highest value since the introduction of the Engels trawl. Catches (median = 1.1 kg;

95th percentile = 19 kg) were similar to those in 1997 (Table 4). Capelin were caught mainly in northern and northeastern Div. 3L (Fig. 2). There were only a few small catches on the plateau of Grand Bank. The distribution in 1998 was broadly similar to that in 1995-97 (Fig. 3).

Frequency of occurrence

As reported by Lilly (1995a), the adjustment of the frequency of occurrence, to take into account the allocation of a relatively large number of sets to certain strata in 1991-94, did not substantially change the estimate of the frequency of occurrence, except in Div. 3L in 1992 (Table 5; Fig. 4). In Div. 2J3K, the adjusted frequency of occurrence increased, with irregular fluctuations, from 20-35% in the early 1980s to 40-50% in the 1990s. With the introduction of the Campelen trawl in 1995, the frequency of occurrence rose to a level higher than previously seen. The value declined in 1996 but increased again in 1997. The 1998 value was the highest in the time-series (unadjusted, 66%; adjusted, 70%). In Div. 3L, the frequency of occurrence fluctuated more widely than in Div. 2J3K. Low values of about 20% in 1990-91 were followed by high values of about 50% in 1992-93 and a decline to an intermediate level of about 40% in 1994. The value in 1995, following the change to the Campelen trawl, was the highest in the time-series. The value declined in 1996, increased in 1997 to the second highest in the time-series and declined in 1998 to the third highest in the time-series (unadjusted, 59%; adjusted, 61%).

Estimates of abundance and biomass

The minimum trawlable abundance and biomass were extremely low in 1978, relatively high in 1979-81, and fluctuated without trend from 1982 to 1994 (Fig. 5). The high levels in Div. 2J in 1978-81 were due almost entirely to a few very large catches on the plateau of Hamilton Bank (Carscadden et al. 1989). The estimates increased dramatically with the introduction of the Campelen trawl in 1995 (Fig. 6). Estimates declined in 1996 but increased in 1997 and 1998. The 1998 abundance estimate was the highest in the time-series and the 1998 biomass estimate equaled 1995 as the highest in the time-series. Biomass estimates, in thousands of tonnes, were as follows since the introduction of the Campelen trawl:

	2J	3K	3L	Total
1995	2.4	42.6	22.6	67.6
1996	0.3	16.7	12.3	29.3
1997	2.6	22.4	17.6	42.6
1998	14.0	36.5	17.2	67.7

Capelin in Div. 3LNO during spring

Distribution

In Div. 3L during the spring of 1998, capelin were recorded at 79% of the 163 fishing stations conducted at depths of 750 m or less (Table 6). This was the highest since the introduction of the Campelen trawl in 1996 and close to the maximum level recorded (80% in 1986). Catches were similar to those in 1996 (median = 2.8 kg; 95th percentile = 82 kg). The distribution was similar to that seen in many years, with largest catches in an arc from the northeast across the northern slope of Grand Bank and down through the Avalon Channel (Fig. 7). Catches were nil or very small in the northeast at depths greater than 300 m and on the plateau of the bank. The broad distribution of moderate to large catches in Div. 3L in 1996-98 is very different from observations in 1991-95, but similar to distributions observed in the mid to late 1980s. One notable difference from earlier years, such as 1986 and 1987, is the high frequency of occurrence of large catches in northern Div. 3L.

In Div. 3N and 3O the frequency of occurrence of capelin was equal to that in 1996 (54%) and much below that in 1997 (78%) (Table 2). However, there were many large catches, especially on the southern half of the plateau of the bank in Div. 3O.

Frequency of occurrence

The frequency of occurrence of capelin in sets at depths <750 m (unadjusted, 79%; adjusted 84%) was the highest in the time-series (Table 7; Fig. 8).

Estimates of biomass

The biomass estimated from areal expansion of mean catch per tow was 73 thousand tons (Table 7; Fig. 9). This was the second highest in the timeseries.

Discussion

Capelin in Div. 2J3KL in the autumn

The autumn distribution of capelin in Div. 2J and 3K changed in the early 1990s. In years prior to 1991 most of the capelin in Div. 2J and 3K were concentrated either in Div. 2J or in central Div. 3K, but after about 1990 or 1991 most of the capelin caught during the bottom-trawl surveys or found in stomachs of cod caught during those surveys came from southeastern Div. 3K (Lilly 1994b, 1995c). In 1997 the distribution was still concentrated toward the southeast but with some indication of a return to the west. In 1998 the distribution was similar to that seen in 1986 and 1987 (Lilly 1995c).

Capelin in Div. 3LNO in the spring

The extensive distribution and moderate to large catches of capelin in Div. 3L in the springs of 1996-98 contrast markedly with the very small catches in 1991-95. This may indicate an increase in the quantity of capelin in the survey area in 1996-98 compared with 1991-95, but the comparison is hampered by the change to the Campelen trawl in 1996.

The catches of capelin in Div. 3O in 1998 were frequent and large. Interpretation of these catches is difficult because of changes in gear and survey timing since the surveys were initiated in 1971 (Lilly 1995b). In some years (e.g. 1976, 1980, 1984, 1986) there were very few capelin caught on the southern Grand Bank, in other years (e.g. 1985, 1993) capelin were caught mainly toward the southern tip of the bank and in a few years (notably 1975 and 1998) there were large catches in central and southwestern 3O. The stock affinity of the capelin caught during these surveys is not clear. They could belong to either the 2+3KL stock or the 3NO stock. In some years capelin may have been intercepted during their migration across 3O to the spawning ground on the Southeast Shoal.

Bottom-trawl catches as indices of capelin status

The frequency of occurrence of capelin in bottom-trawl catches and the minimum trawlable biomass calculated from those catches have been presented for both the autumn survey series in Div. 2J3KL and the spring survey series in Div. 3L. The extent to which either of these metrics may serve as an index of capelin abundance or biomass is not known. It is useful to consider the question in two steps: (1) how well do the frequency of occurrence and the estimate of biomass reflect the quantity of capelin in the trawl survey area at the time of the survey and (2) how does the latter reflect the total abundance or biomass of the capelin stock? With respect to part (1), Lilly (1995b) found that both the frequency of occurrence and the trawlable biomass calculated for the spring series in Div. 3L were positively (but not significantly) related to the biomass of capelin estimated from the spring acoustic surveys. The lack of significance may be due in part to poor overlap in time and space between the acoustic survey and the bottom-trawl survey. More information is needed on the relationship between catches in a bottom trawl and the density and behaviour of capelin in the immediate vicinity as measured and observed with hydroacoustics. It is possible that a large catch of capelin in a bottom trawl indicates a high density of capelin near the bottom, especially since large catches are frequently taken close together, often in sequential sets. However, large catches could occur when the survey encounters capelin in relatively shallow water. For example, large catches of capelin on Hamilton Bank in 1979-81 (Carscadden et al. 1989) contributed to high estimates of trawlable biomass at a time when Soviet and Canadian acoustic surveys indicated that the abundance of the SA2+Div.3K capelin stock was low (Lilly 1994b). It is also possible that changes in the behaviour of capelin may change their vulnerability to a bottom trawl. For example, if capelin tend to stay near the bottom in both night and day, instead of migrating upward at night as has often been observed, then they may be captured more frequently and in greater quantities. Shackell et al. (1994b) reported that the capelin found during the acoustic survey of Div. 3L in spring 1992 were relatively deep and did not surface at night as in previous years. Such behaviour might result in an upward bias in the frequency of occurrence and the estimate of biomass.

The second part of the question relates to the distribution of the capelin at the time of the bottom-trawl survey. Frank et al. (1996) reported that capelin increased in abundance outside their normal range during periods of anomalously low sea temperatures. They speculated that these changes in distribution, particularly the appearance of capelin on the Flemish Cap, could explain, in part, the dramatic decline in estimates of capelin abundance from spring acoustic surveys beginning in 1991. Such large-scale migrations to areas outside Div. 2J3KL could affect bycatches in both the spring and autumn bottom-trawl surveys. Bycatches in the spring survey might also be affected by changes in the timing of the capelin migration relative to the timing of the survey. Both the timing of the capelin migration into southern Div. 3L and the timing of their spawning on beaches of eastern Newfoundland are variable and related in part to changes in water temperature (Shackell et al. 1994a, Nakashima 1996, Carscadden et al. 1997). In addition, the time of the spring bottom-trawl survey in Div. 3L has become retarded by about one month in recent years compared with the 1980s. This delay in the survey might increase the degree of spatial overlap with capelin if the capelin migration is also delayed, but the degree of overlap cannot be assessed.

References

Bishop, C. A. 1994. Revisions and additions to stratification schemes used during research vessel surveys in NAFO Subareas 2 and 3. NAFO SCR Doc. 94/43, Serial No. N2413. 23p.

Brodie, W. 1996. A description of the 1995 fall groundfish survey in Division 2J3KLNO. NAFO SCR Doc. 96/27, Serial No. N2700. 7 p.

Carscadden, J., D. S. Miller, and G. R. Lilly. 1989. Capelin in SA2 + Div. 3K: results from offshore research. CAFSAC Res. Doc. 89/78. 44 p.

Carscadden, J., B. S. Nakashima, and K. T. Frank. 1997. Effects of fish length and temperature on the timing of peak spawning in capelin (Mallotus villosus). Can. J. Fish. Aquat. Sci. 54: 781-787.

Carscadden, J., B. Nakashima, R. Harnum, and G. Lilly. 1990. Capelin in SA 2 and Div. 3K. CAFSAC Res. Doc. 90/7. 28 p.

Doubleday, W. G. (ed.) 1981. Manual on groundfish surveys in the Northwest Atlantic. NAFO Sci. Coun. Studies 2: 7-55.

Frank, K. T., J. E. Carscadden, and J. E. Simon. 1996. Recent excursions of capelin (Mallotus villosus) to the Scotian Shelf and Flemish Cap during anomalous hydrographic conditions. Can. J. Fish. Aquat. Sci. 53: 1473-1486.

Lilly, G. R. 1992. By-catches of capelin in Canadian bottom-trawl surveys from northern Labrador to the southern Grand Bank (Div. 2GHJ3KLNO) in autumn 1991. NAFO SCR Doc. 92/8, Serial No. N2041. 7 p.

Lilly, G. R. 1994a. By-catches of capelin in bottom-trawl surveys, p. 99-107. In: J. Carscadden [ed.] Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 94/18.

Lilly, G. R. 1994b. Predation by Atlantic cod on capelin on the southern Labrador and Northeast Newfoundland shelves during a period of changing spatial distributions. ICES mar. Sci. Symp. 198: 600-611.

Lilly, G. R. 1995a. By-catches of capelin during autumn bottom trawl surveys in Divisions 2J3KLNO, with emphasis on 1994, p. 93-109. In: Anon. [ed.] Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 95/70.

Lilly, G. R. 1995b. By-catches of capelin during spring bottom-trawl surveys in Divisions 3LNO, p. 110-132. In: Anon. [ed.] Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 95/70.

Lilly, G. R. 1995c. Did the feeding level of the cod off southern Labrador and eastern Newfoundland decline in the 1990s? DFO Atl. Fish. Res. Doc. 95/74. 25 p.

Lilly, G. R. 1996. By-catches of capelin and Arctic cod during bottom trawl surveys in NAFO Divisions 2J3KL, p. 218-242. In: Anon. [ed.] Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 96/90.

Lilly, G.R. 1997. By-catches of capelin during spring and autumn bottom-trawl surveys in Divisions 2J3KL in 1996. In: Anon. [ed.] Capelin in SA2 + Div. 3KL. CSAS Res. Doc. 97/29. pp. 91-124.

Lilly, G.R. 1998. By-catches of capelin during spring and autumn bottom-trawl surveys in Divisions 2J3KL in 1997. In: Anon. [ed.] Capelin in SA2 + Div. 3KL. CSAS Res. Doc. 98/63. pp. 79-113.

Lilly, G. R., and D. J. Davis. 1993. Changes in the distribution of capelin in Divisions 2J, 3K and 3L in the autumns of recent years, as inferred from bottom-trawl by-catches and cod stomach examinations. NAFO SCR Doc. 93/54, Serial No. N2237. 14 p.

Lilly, G. R., P. A. Shelton, J. Brattey, N. Cadigan, E. F. Murphy, D. E. Stansbury, M. B. Davis, and M. J. Morgan. 1998. An assessment of the cod stock in NAFO Divisions 2J+3KL. DFO CSAS Res. Doc. 98/15. 102 p.

McCallum, B. R., and S. J. Walsh. 1997. Groundfish survey trawls used at the Northwest Atlantic Fisheries Centre, 1971 to present. NAFO Sci. Coun. Studies 29: 93-104.

Miller, D. S., and G. R. Lilly. 1991. Observations and studies on SA2 + Div. 3K capelin in 1990. CAFSAC Res. Doc. 91/11. 30 p.

Nakashima, B. S. 1996. The relationship between oceanographic conditions in the 1990s and changes in spawning behaviour, growth and early life history of capelin (Mallotus villosus). NAFO Sci. Coun. Studies 24: 55-68.

Shackell, N. L., J. E. Carscadden, and D. S. Miller. 1994a. Migration of pre-spawning capelin (Mallotus villosus) as related to temperature on the northern Grand Bank, Newfoundland. ICES J. mar. Sci. 51: 107-114.

Shackell, N. L., J. E. Carscadden, and D. S. Miller. 1994b. Diel vertical migration of capelin (Mallotus villosus) and its effect on acoustic estimates of density. ICES C.M. 1994/Mini:5. 18 p.

Table 1. Selected data for bottom-trawl surveys in Divisions 2J3KL in the autumns of 1977-1998. AN = ALFRED NEEDLER, ATC = A. T. CAMERON, GA = GADUS ATLANTICA, TE = TELEOST, WT = WILFRED TEMPLEMAN.

Year	Div.	Ship/Trip	Sampling dates (d/mo.-d/mo.)	Number of stations occupied		Phase 1 stations with cod		Phase 1 stations with capelin	
				Phase 1	Phase 2	No.	%	No.	%
1977	2J3K	GA 3	11/11-02/12	127		96	76	7	6
1978	2J3K	GA 15	04/11-27/11	125		122	98	2	2
1979	2J3K	GA 29	15/11-04/12	124		121	98	42	34
1980	2J3K	GA 44	22/11-08/12	134		129	96	25	19
1981	2J3K	GA 58,59	14/11-13/12	224		182	81	53	24
	3L	ATC 323,325	03/10-18/11	97		87	90	13	13
1982	2J3K	GA 71,72	30/10-08/12	303		251	83	97	32
	3L	ATC 333,334	30/10-06/12	121		113	93	43	36
1983	2J3K	GA 86-88	28/10-07/12	255		220	86	57	22
	3L	WT 7-9	13/10-14/11	126		122	97	44	35
1984	2J3K	GA 101-103	27/10-05/12	262		219	84	67	26
1985	2J3K	GA 116-118	23/10-02/12	311		251	81	127	41
	3L	WT 37-39	09/10-18/11	232		189	82	80	34
1986	2J3K	GA 131-133	03/11-11/12	215		185	86	52	24
	3L	AN 72	13/11-30/11	142		119	84	38	27
1987	2J3K	GA 145-147	29/10-08/12	288		252	88	94	33
	3L	WT 65	15/10-01/11	165		149	90	38	23
1988	2J3K	GA 159-161	04/11-13/12	239		209	87	84	35
	3L	WT 78	26/10-13/11	189		167	88	85	45
1989	2J3K	GA 174-176	02/11-19/12	276	48	228	83	134	49
	3L	WT 87	12/10-31/10	174	21	134	77	72	41
1990	2J3K	GA 190-192	03/11-19/12	243	68	178	73	83	34
	3L	WT 101	18/10-18/11	161	27	140	87	31	19

Table 1. (Cont'd.)

				Number of stations occupied		Phase 1 stations with cod		Phase 1 stations with capelin	
Year	Div.	Ship/Trip	Sampling dates (d/mo.-d/mo.)	Phase 1	Phase 2	No.	%	No.	%
1991	2J3K	GA 208-210	06/11-17/12	313		229	73	117	37
	3L	WT 114,115	08/11-02/12	219		168	77	45	21
1992	2J3K	GA 224-226	29/10-09/12	319		209	66	153	48
	3L	WT 129,130	05/11-29/11	215		146	68	80	37
1993	2J3K	GA 236-238	30/10-06/12	263		137	52	98	37
	3L	WT 145,146	12/11-04/12	153		94	61	76	50
1994	2J3K	GA 250-252	09/11-19/12	255		81	32	108	42
	3L	WT 161,162	08/11-07/12	200		68	34	83	42
1995	2J3K	TE 20-23 WT 180, 181	28/11-25/01	215		155	72	116	54
	3L	TE 23 WT 176, 178, 179	03/10-25/01	166		69	42	117	71
1996	2J3K	TE 39-41 WT 198	22/10-26/11	291		180	62	139	48
	3L	TE 41 WT 196-198	09/10-05/12	210		75	36	97	46
1997	2J3K	TE 54-57 WT 217	19/10-19/12	292		158	54	164	56
	3L	TE 57-58 WT 213-217	23/10-20/12	205		98	48	119	58
1998	2J3K	TE 72-75 WT 232	20/10-30/11	289		173	60	170	59
	3L	TE 75-76 WT 230-233	02/11-15/12	204		78	38	103	50

Table 2. Selected data for bottom-trawl surveys in Div. 3LNØ in the springs of 1971-98.

Year	Div.	Ship/Trip	Sampling Dates (d/mo.-d/mo.)	No. of stations occupied	Stations with cod		Stations with capelin	
					No.	%	No.	%
1971	3L	ATC 187	03/06-18/06	60	55	92	25	42
	3NØ	ATC 187	09/06-13/06	25	23	92	7	28
1972	3L	ATC 199	12/05-18/05	38	38	100	16	42
	3NØ	ATC 199	04/05-12/05	45	44	98	6	13
1973	3L	ATC 208, 209	07/04-06/05	33	27	82	3	9
	3NØ	ATC 207-209	22/03-04/05	96	80	83	17	18
1974	3L	ATC 222	07/05-21/05	70	57	81	17	24
	3NØ	ATC 222	08/05-13/05	37	30	81	3	8
1975	3L	ATC 233	09/05-25/05	55	47	86	39	71
	3NØ	ATC 233	15/05-24/05	58	45	78	24	41
1976	3L	ATC 246	23/04-03/05	64	60	94	30	47
	3NØ	ATC 245	02/04-13/04	78	58	74	4	5
1977	3L	ATC 262	04/05-18/05	102	92	90	36	35
	3NØ	ATC 263	26/05-07/06	88	77	88	12	14
1978	3L	ATC 276	06/05-17/05	95	86	91	8	8
	3NØ	ATC 276, 277	14/05-07/06	92	78	85	5	5
1979	3L	ATC 290	17/05-04/06	141	134	95	42	30
	3NØ	ATC 289, 291	02/04-25/06	172	133	77	21	12
1980	3L	ATC 304, 305	10/05-02/06	115	113	98	20	17
	3NØ	ATC 303, 304	11/04-11/05	140	109	78	4	3
1981	3L	ATC 317, 318	06/04-07/05	81	67	83	28	35
	3NØ	ATC 318, 319	04/05-22/05	77	67	87	10	13
1982	3L	ATC 329	06/05-17/05	103	93	90	44	43
	3NØ	ATC 327, 328	27/03-26/04	138	119	86	20	15
1984	3L	AN 28	17/05-21/05	37	37	100	18	49
	3NØ	AN 27	28/04-08/05	117	86	74	15	13
1985	3L	WT 28-30	17/04-26/05	221	198	90	94	43
	3NØ	WT 29 AN 43	11/04-05/05	178	134	75	33	19

Table 2. Continued ...

Year	Div.	Ship/Trip	Sampling Dates (d/mo.-d/mo.)	No. of stations occupied	Stations with cod		Stations with capelin	
					No.	%	No.	%
1986	3L	WT 48	07/05-25/05	211	203	96	169	80
	3NO	WT 47	18/04-04/05	203	160	79	21	10
1987	3L	WT 59, 60	14/05-01/06	181	169	93	53	29
	3NO	WT 58, 59	23/04-14/05	190	168	88	56	29
1988	3L	WT 70, 71	05/05-24/05	154	142	92	108	70
	3NO	WT 70	21/04-05/05	161	132	82	28	17
1989	3L	WT 82,83	06/05-28/05	205	189	92	157	77
	3NO	WT 82	20/04-06/05	195	155	80	47	24
1990	3L	WT 96	18/05-04/06	156	137	88	108	69
	3NO	WT 94-96	22/04-01/06	178	146	82	59	33
1991	3L	WT 106, 107	11/05-29/05	143	89	62	69	48
	3NO	WT 105, 106	19/04-11/05	209	128	61	44	21
1992	3L	WT 120-122	13/05-07/06	178	51	29	92	52
	3NO	WT 119, 120	22/04-13/05	185	90	49	54	29
1993	3L	WT 137, 138	18/05-10/06	181	55	30	93	51
	3NO	WT 136, 137	27/04-18/05	166	77	46	67	40
1994	3L	WT 153, 154	22/05-10/06	160	18	11	75	47
	3NO	WT 152, 153	30/04-22/05	157	44	28	48	31
1995	3L	WT 169, 170	27/05-14/06	151	19	13	78	52
	3NO	WT 168, 169	03/05-27/05	174	51	29	42	24
1996	3L	WT 189-191	30/05-27/06	189	82	43	138	73
	3NO	WT 188, 189	07/05-30/05	168	100	60	91	54
1997	3L	WT 206-208	04/06-26/06	158	40	25	122	77
	3NO	WT 204-206	30/04-04/06	152	80	53	118	78
1998	3L	WT 223-224	06/06-30/06	163	51	31	129	79
	3NO	WT 221-222	12/05-04/06	181	101	56	97	54

Table 3. Statistics for by-catches of capelin during bottom-trawl surveys in NAFO Div. 2J3K during the autumns of 1978 to 1998.

Year	Number[a] of stations	Stations with capelin		Percentiles of capelin[b] catches (kg)			
		No.	%	50	75	95	Max.
1978	125	2	2	0.03			<<1
1979	124	42	34	0.09	0.3	9	185
1980	134	25	19	0.50	1.8	149	172
1981	214	53	25	0.30	1.0	234	345
1982	291	97	33	0.20	0.5	3	18
1983	248	58	23	0.10	0.3	2	24
1984	251	67	27	0.15	0.4	2	3
1985	297	127	43	0.12	0.4	3	10
1986	209	50	24	0.18	0.8	12	24
1987	276	94	34	0.20	1.0	18	117
1988	233	84	36	0.15	0.8	3	39
1989	273[c]	134	49	0.12	0.3	2	32
1990	232[c]	82	35	0.09	0.3	1	11
1991[d]	302	117	39	0.14	0.5	4	68
1992[d]	308	151	49	0.10	0.3	3	15
1993[d]	245	98	40	0.14	0.5	6	9
1994[d]	237	108	46	0.50	1.9	10	30
1995[e]	194	116	60	2.31	8.3	56	332
1996[e]	234	122	52	0.99	3.3	21	53
1997[e]	236	146	62	1.96	6.7	20	49
1998[e]	233	153	66	2.22	9.7	46	132

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[a] Stations in depths >750 m are not included. Stations in strata 618 and 619 on the coastal shelf off northern Newfoundland are included, but stations in strata 608-616 in the inshore area of 3K are not included. Strata 618 and 619 were not fished prior to 1984, and strata 608-616 were added in 1996.

[b] Percentiles are calculated for those stations in which capelin were recorded in the catch.

[c] Only stations from first-stage sampling are included.

[d] Surveys in 1991-94 are not directly comparable to those in other years, because the number of fishing stations assigned to each stratum was not roughly proportional to stratum area.

[e] Survey was conducted with a Campelen 1800 shrimp trawl. Earlier surveys were conducted with an Engel 145 Hi-Lift trawl.

Table 4. Statistics for by-catches of capelin during bottom-trawl surveys in NAFO Div. 3L during the autumns of 1985 to 1998.

Year	Number[a] of stations	Stations with capelin		Percentiles of capelin[b] catches (kg)			
		No.	%	50	75	95	Max.
1985	232	80	35	0.33	0.8	6	16
1986	142	38	27	0.11	0.4	2	6
1987	165	38	23	0.10	0.5	2	4
1988	189	85	45	0.20	0.8	7	21
1989	174[c]	72	41	0.20	0.4	7	30
1990	161[c]	31	19	0.10	0.5	11	17
1991[d]	219	45	21	0.11	0.5	7	10
1992[d]	215	80	37	0.12	0.4	2	6
1993[d]	153	76	50	0.13	0.4	3	16
1994[d]	200	83	42	0.10	0.3	1	2
1995[e]	162	117	72	1.26	6.3	29	70
1996[e]	148	78	53	0.48	3.9	17	92
1997[e]	141	93	66	1.09	4.1	19	47
1998[e]	140	82	59	1.06	3.3	19	78

[a] Stations in depths >750 m are not included. Stations in strata 784-799, which were added in the inshore area in 1996,and stratum 800, which was added in 1997, are not included.

[b] Percentiles are calculated for those stations in which capelin were recorded in the catch.

[c] Only stations from first-stage sampling are included.

[d] Surveys in 1991-94 are not directly comparable to those in other years, because the number of fishing stations assigned to each stratum was not roughly proportional to stratum area.

[e] Survey was conducted with a Campelen 1800 shrimp trawl. Earlier surveys were conducted with an Engels 145 Hi-Lift trawl.

Table 5. The frequency of occurrence of capelin in catches during the autumn bottom-trawl surveys in Div. 2J3K and Div. 3L in 1978-98. Div. 3L was not surveyed in 1978-80 and 1984. Only sets in 750 m or less are included. Sets in the inshore strata of Div. 3K and 3L are deleted. The method of adjustment is described in the text. For 1989 and 1990, the unadjusted value includes only sets from phase 1, whereas the adjusted value includes sets from phases 1 and 2. The tows in Div. 3L in 1981-83 were conducted with a Yankee 41-5 bottom trawl. All other tows prior to 1995 were conducted with an Engel 145 Hi-Lift bottom trawl. Tows in 1995-98 were conducted with a Campelen 1800 shrimp trawl.

Year	2J3K unadj.	2J3K adj.	3L unadj.	3L adj.
1978	1.6	1.3		
1979	33.9	35.0		
1980	18.7	18.4		
1981	24.8	26.4	13.4	14.1
1982	33.3	33.6	35.5	28.8
1983	23.4	24.8	34.9	30.6
1984	26.7	26.4		
1985	42.8	43.7	34.5	34.3
1986	23.9	26.1	26.8	27.0
1987	34.1	35.3	23.0	26.6
1988	36.1	36.9	45.0	45.5
1989	49.1	48.8	41.4	39.8
1990	35.3	35.2	19.3	21.0
1991	38.7	43.3	20.5	22.9
1992	49.0	53.0	37.2	52.1
1993	40.0	47.4	49.7	52.8
1994	45.6	46.7	41.5	38.7
1995	59.8	66.2	72.2	76.1
1996	52.1	54.2	52.7	56.6
1997	61.9	65.1	66.0	69.4
1998	65.7	70.0	58.6	61.2

Table 6. Statistics for by-catches of capelin during bottom-trawl surveys in NAFO Div. 3L during the springs of 1971 to 1998.

Year	Ship[a] and trip number	Number[b] of stations	Stations with capelin		Percentiles of capelin catches[c] (kg)			
			No.	%	50	75	95	Max.
1971	ATC 187	60	25	42	4.54	14.3	135	181
1972	ATC 199	38	16	42	1.24	4.5	9	9
1973	ATC 208,209	33	3	9	0.14	21.8	22	22
1974	ATC 222	70	17	24	1.13	9.3	58	58
1975	ATC 233	55	39	71	0.91	6.2	145	544
1976	ATC 246	64	30	47	1.86	6.0	17	18
1977	ATC 262	102	36	35	0.89	4.5	119	255
1978	ATC 276	95	8	8	0.07	0.3	<1	<1
1979	ATC 290	141	42	30	0.80	8.4	137	227
1980	ATC 304,305	115	20	17	0.48	1.6	12	13
1981	ATC 317,318	81	28	35	1.00	2.4	18	20
1982	ATC 329	103	44	43	0.50	2.9	27	48
1983								
1984	AN 28	37	18	49	3.25	11.5	190	190
1985	WT 28-30	221	94	43	0.30	1.4	8	24
1986	WT 48	211	169	80	2.00	6.0	72	483
1987	WT 59,60	181	53	29	4.50	17.0	69	167
1988	WT 70,71	154	108	70	0.30	1.7	12	33
1989	WT 82,83	205	157	77	0.80	2.1	18	32
1990	WT 96	156	108	69	0.98	3.2	52	175
1991	WT 106,107	143	69	48	0.14	0.5	5	24
1992	WT 120-122	178	92	52	0.04	0.1	1	4
1993	WT 137,138	181	93	51	0.09	0.4	5	26
1994	WT 153,154	152	74	49	0.11	0.3	2	4
1995	WT 169,170	151	78	52	0.08	0.3	6	12
1996	WT 189-191	189	138	73	3.92	15.1	78	625
1997	WT 206-208	158	122	77	1.37	5.5	17	40
1998	WT 223-224	163	129	79	2.77	10.8	82	468

[a] ATC = A. T. Cameron, AN = Alfred Needler, WT = Wilfred Templeman

[b] Stations in depths >750 m are not included.

[c] Percentiles are calculated for those stations in which capelin were recorded in the catch.

Table 7. The frequency of occurrence and trawlable biomass of capelin in Div. 3L in the springs of 1977-98, as estimated from bottom trawl surveys. There was no bottom-trawl survey in 1983, and the survey in 1984 was incomplete. Tows were made with a Yankee 41-5 trawl in 1977-82, an Engel 145 Hi-Lift trawl in 1985-95, and a Campelen 1600 trawl in 1996-98.

	Frequency of occurrence (%)		Biomass ('000 tons)
Year	Unadj.	Adj.	Bottom trawl survey
1977	35.3	38.2	18.246
1978	8.4	5.9	0.025
1979	29.8	31.7	15.441
1980	17.4	15.6	0.492
1981	34.6	28.5	2.045
1982	42.7	47.9	6.005
1983			
1984			
1985	42.5	41.0	1.874
1986	80.1	79.7	33.864
1987	29.3	32.1	12.919
1988	70.1	69.8	4.007
1989	76.6	78.0	6.250
1990	69.2	71.5	15.546
1991	48.3	52.1	1.398
1992	51.7	54.1	0.259
1993	51.4	53.1	1.436
1994	48.7	48.6	0.432
1995	51.7	55.8	1.103
1996	73.0	77.7	94.695
1997	77.2	81.3	19.970
1998	79.1	83.6	73.363

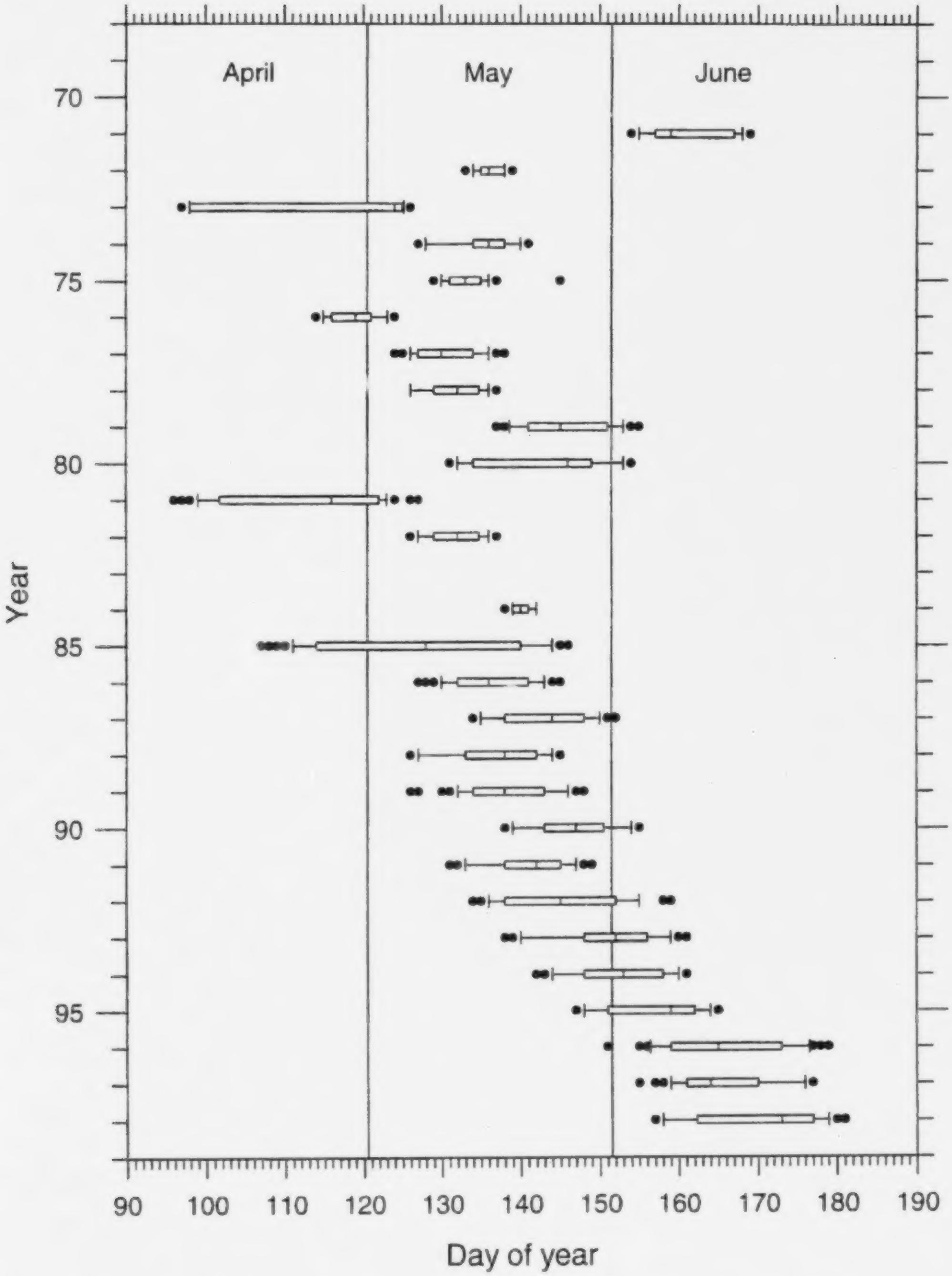

Fig. 1. Dates of fishing during stratified-random bottom-trawl surveys in Division 3L in 1971-1998. The box plot for each year illustrates the 10th, 25th, 50th, 75th and 90th percentiles, and all dates beyond the 10th and 90th percentiles.

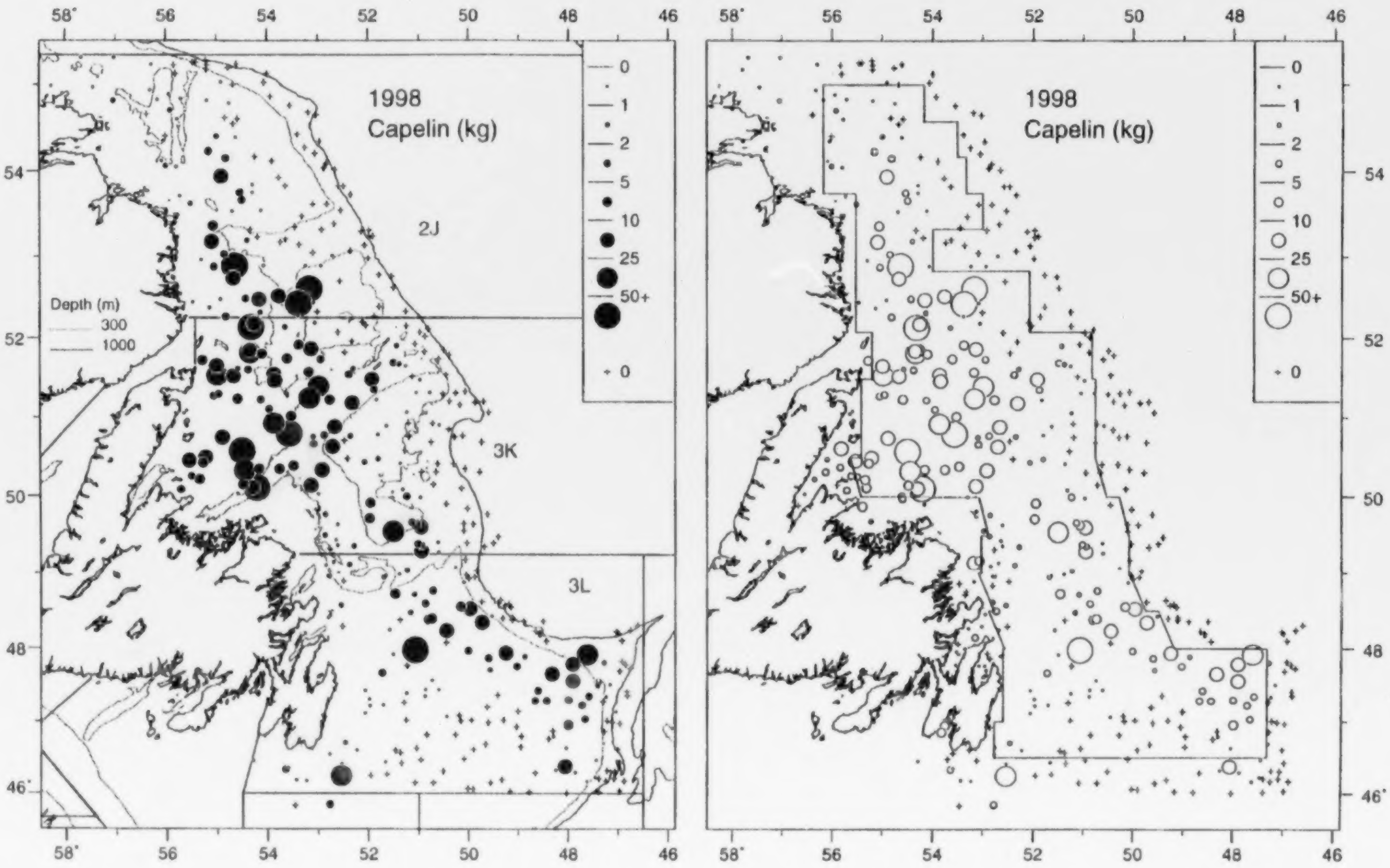
1998
Capelin (kg)
0
1
2
5
10
25
50+
0
Depth (m)
300
1000
2J
3K
3L
58°
56
54
52
50
48
46
54
52
50
48
46°

Fig. 2. Capelin catches (kg/15 min tow) during random-stratified bottom-trawl surveys in Divisions 2J3KL during autumn 1998. The left panel shows the 300 and 1000m isobaths. The right panel shows the boundary of the acoustic survey in 1994. Inshore stations are illustrated in the right panel only.

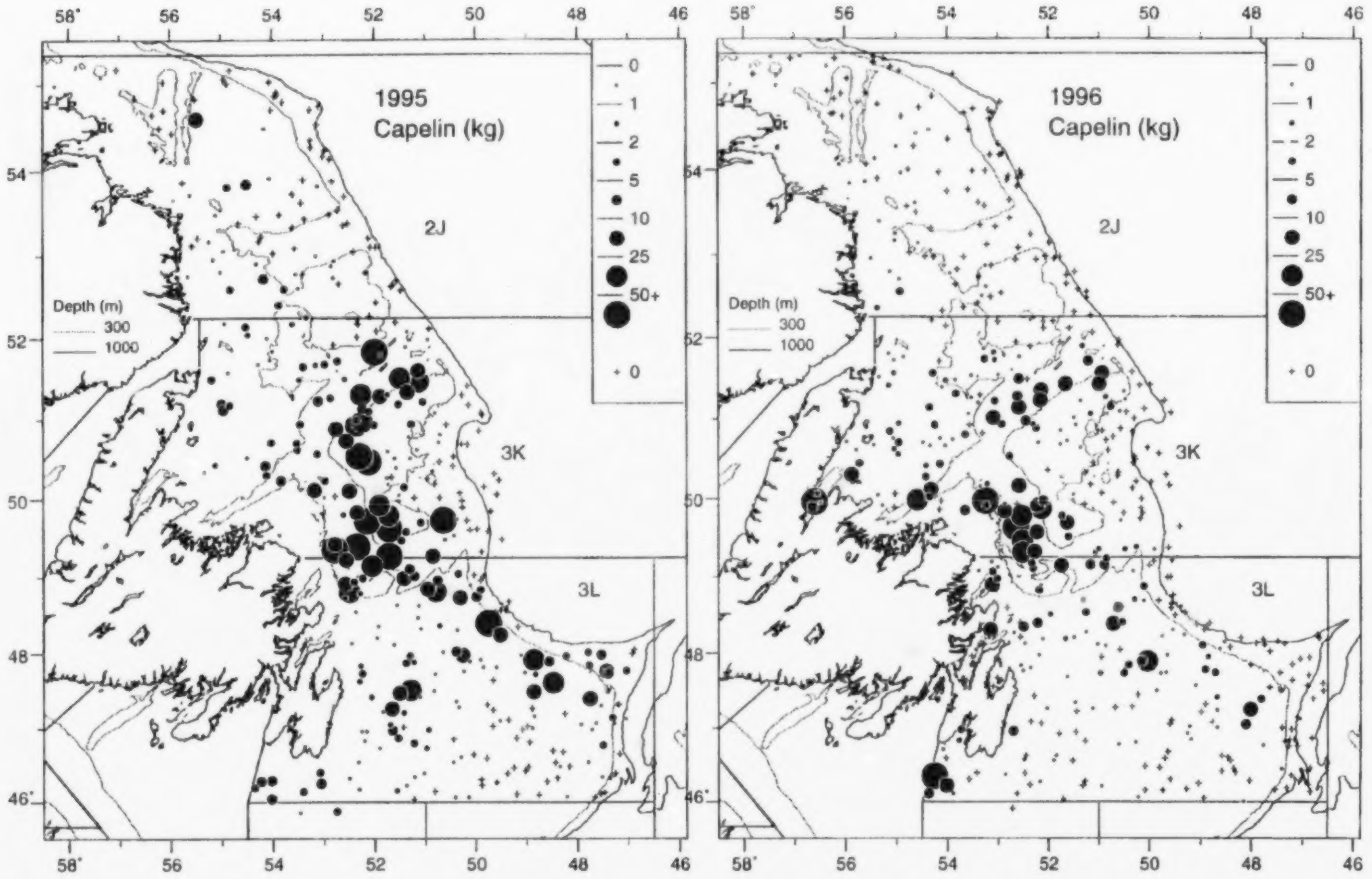
1995
Capelin (kg)
2J
3K
3L
Depth (m)
300
1000
0
1
2
5
10
25
50+
0
58˚
56
54
52
50
48
46
54
52
50
48
46˚
1996
Capelin (kg)
2J
3K
3L
Depth (m)
300
1000
0
1
2
5
10
25
50+
0

Fig. 3. Capelin catches (kg/15 min tow) during random-stratified bottom-trawl surveys in Divisions 2J3KL during the autumns of . 1995-1998.

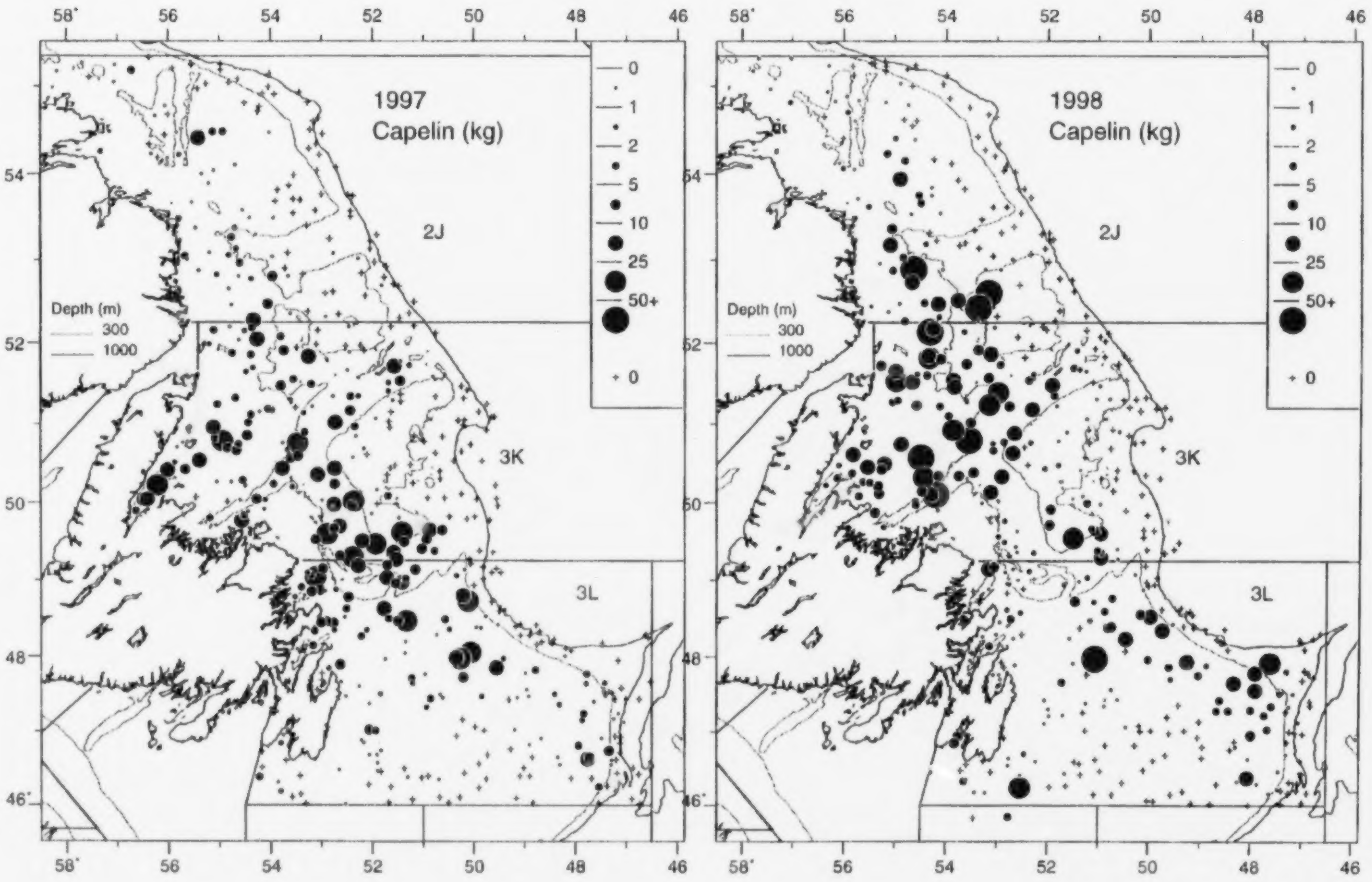
1997
Capelin (kg)
1998
Capelin (kg)
2J
3K
3L
0
1
2
5
10
25
50+
+ 0
Depth (m)
300
1000
58°
56
54
52
50
48
46
54
52
50
48
46°

Fig. 3 (cont'd)

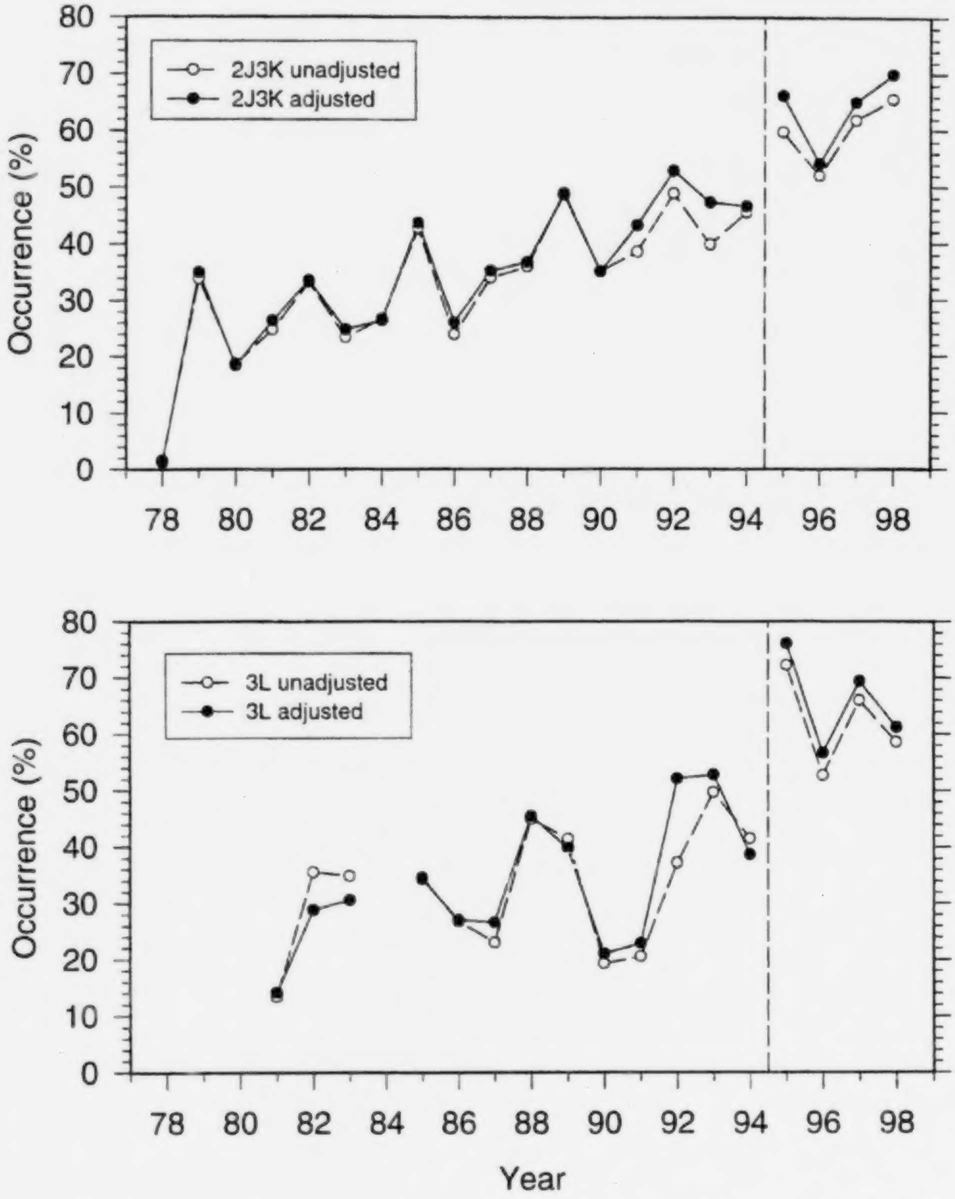

Fig. 4. The frequency of occurrence of capelin in catches during the autumn bottom-trawl surveys in Division 2J3K (upper panel) and Division 3L (lower panel) in 1978-1998. Division 3L was not surveyed in 1978-1980 and 1984. A Yankee 41-5 trawl was used in Division 3L in 1981-1983. An Engel 145 Hi-Lift trawl was used in Division 3L in 1985-1994 and in Division 2J3K in 1978-1994. A Campelen 1800 shrimp trawl was used in all Divisions in 1995-1998.

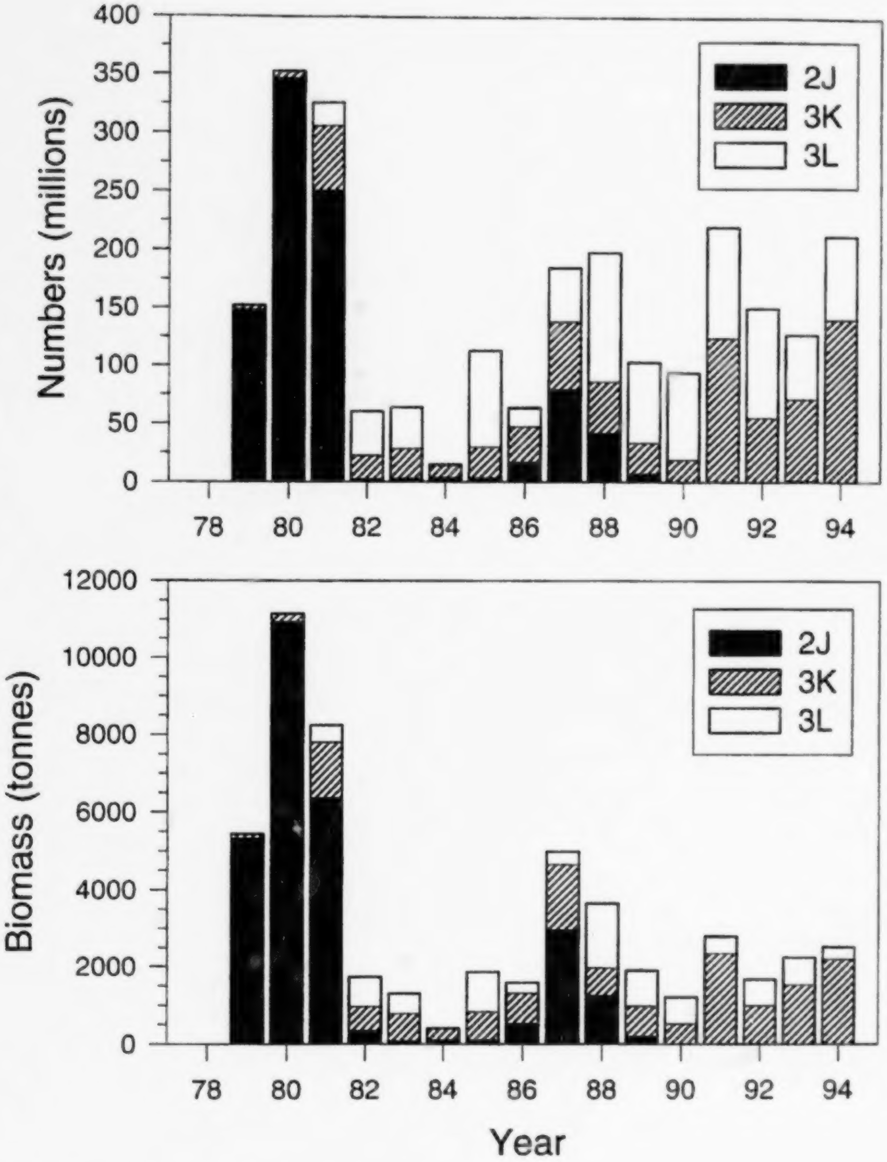

Fig. 5. Abundance and biomass of capelin by year and Division, estimated from areal expansion of stratified mean catch per tow during autumn surveys, for the years 1978-1994. There was a survey in Divisions 2J3K in 1978, but the estimated levels were too small to be distinguishable from the axis. Division 3L was not surveyed in 1978-1980 and 1984.

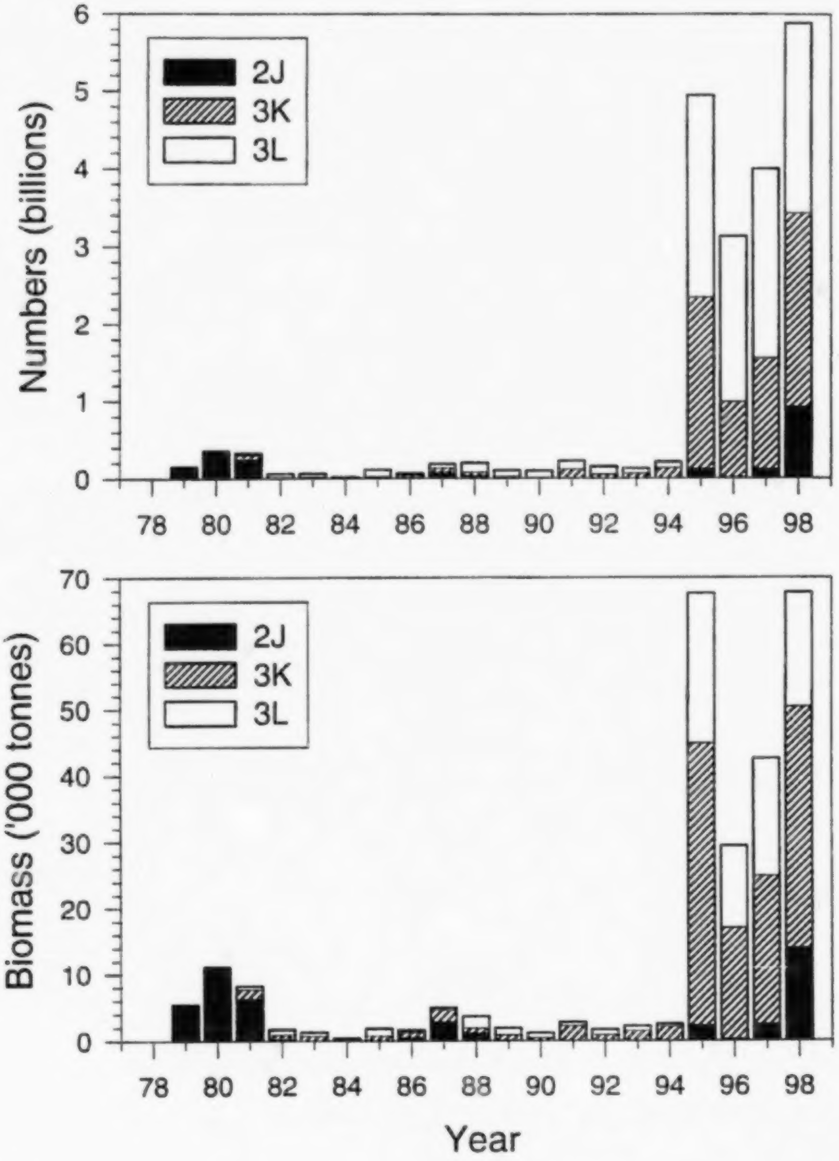

Fig. 6. Abundance and biomass of capelin by year and Division, estimated from areal expansion of stratified mean catch per tow during autumn surveys, for the years 1978-1998. There was a survey in Divisions 2J3K in 1978, but the estimated levels were too small to be distinguishable from the axis. Division 3L was not surveyed in 1978-1980 and 1984. A Campelen 1800 shrimp trawl was introduced in 1995.

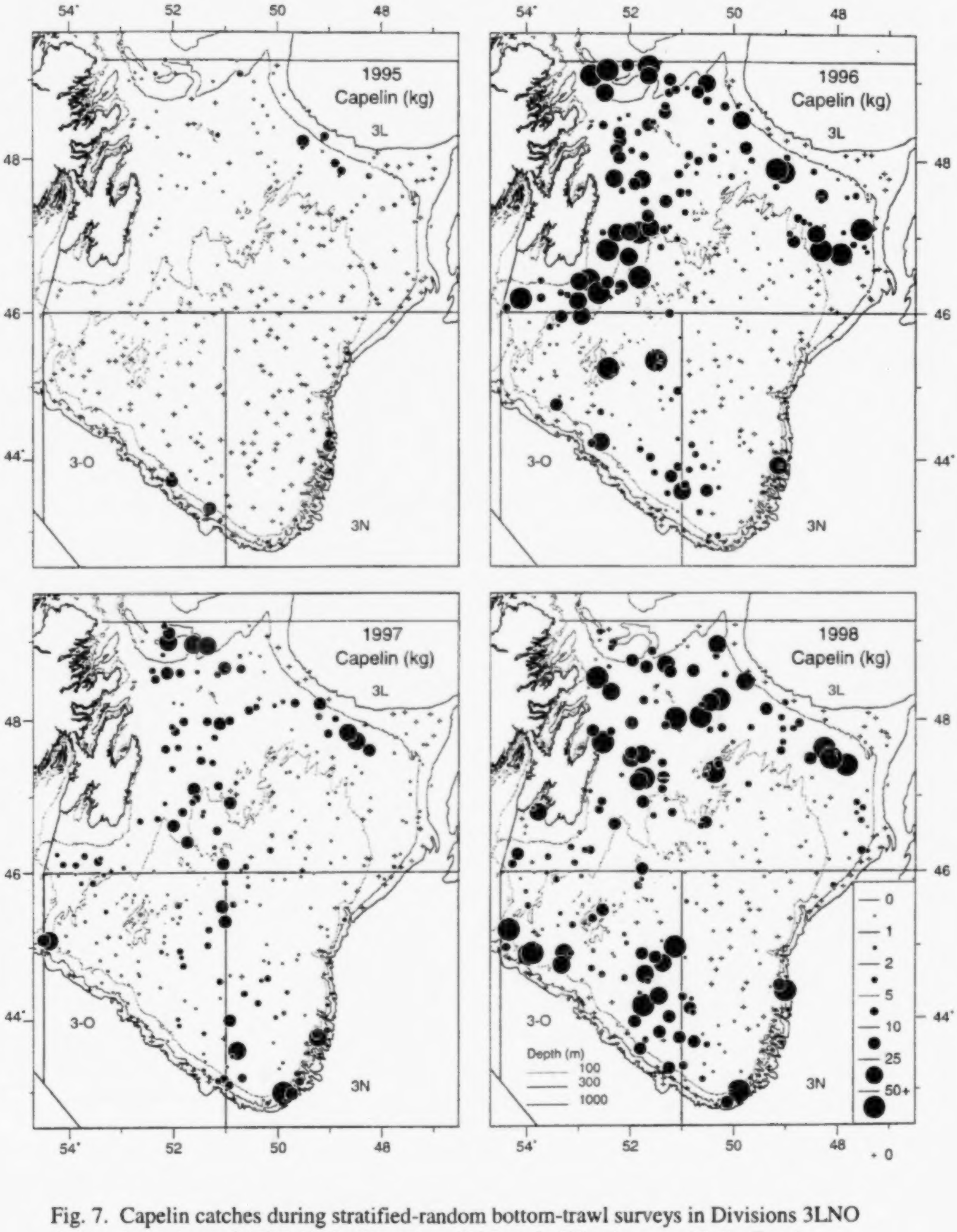
54°
52
50
48
1995
Capelin (kg)
1996
Capelin (kg)
1997
Capelin (kg)
1998
Capelin (kg)
3L
3-O
3N
48
46
44°
Depth (m)
100
300
1000
0
1
2
5
10
25
50+
+ 0

Fig. 7. Capelin catches during stratified-random bottom-trawl surveys in Divisions 3LNO during the springs of 1995-1998. Data from 1995 are kg/30 min tow with the Engels trawl and data from 1996-1998 are kg/15 min tow with the Campelen trawl. For plots of distributions in 1971-1994, see Lilly (1995b).

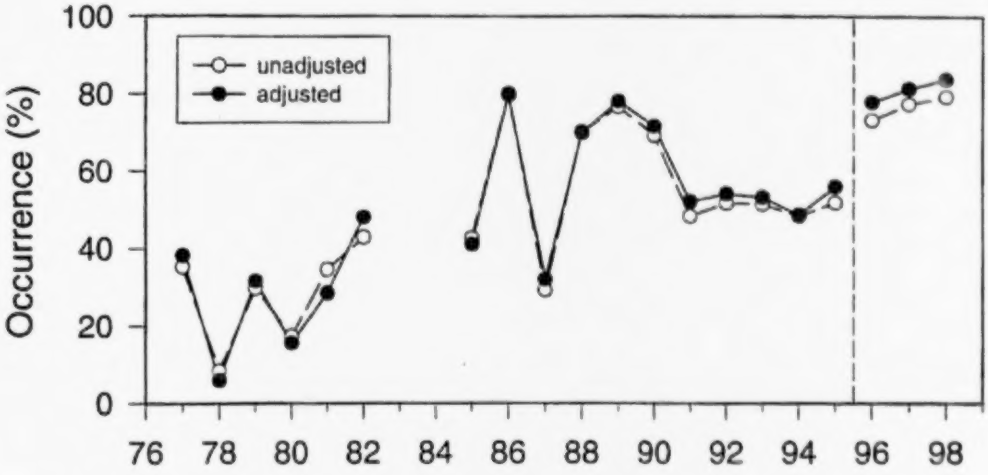

Fig. 8. The frequency of occurrence of capelin in catches during spring bottom-trawl surveys in Division 3L in 1977-1998. There was no survey in 1983 and coverage was inadequate in 1971-1976 and 1984. A Yankee 41-5 trawl was used until 1982, an Engels 145 Hi-Lift trawl was used in 1985-1995, and a Campelen 1600 shrimp trawl was used in 1996-1998.

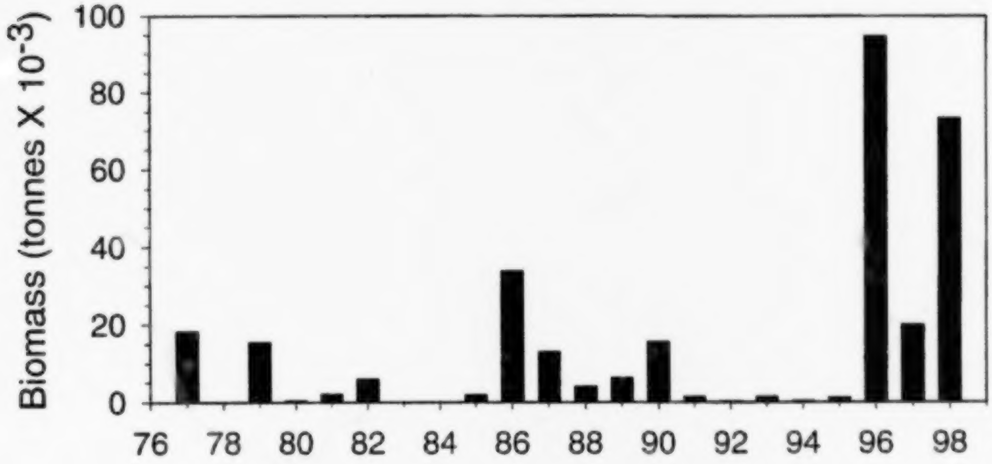

Fig. 9. The biomass of capelin as estimated from areal expansion of stratified mean catch per tow during spring bottom-trawl surveys in Division 3L in 1977-1998. There was no survey in 1983 and coverage was inadequate in 1971-1976 and 1984. A Yankee 41-5 trawl was used until 1982, an Engels 145 Hi-Lift trawl was used in 1985-1995, and a Campelen 1600 shrimp trawl was used in 1996-1998.

Absolute Abundance and Biomass of Juvenile and Adult Capelin (Mallotus villosus) in the Newfoundland Region (2J3KLNO) Estimated from the Pelagic Juvenile Fish Surveys, 1994-1998

by

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Introduction

The absolute abundance and biomass of capelin (Mallotus villosus) within the Newfoundland Region (NAFO 2J3KLNO) is of interest to scientists and managers for many reasons. These include setting catch limits as part of the capelin management plan. Currently, there is no direct estimate of capelin biomass, following the cancellation of the offshore capelin acoustic surveys previously carried out in spring and autumn. A multiplicative model developed from many indices and modelled over many years indicates that the abundance and biomass of capelin is similar to, or possibly larger than, the absolute estimates of capelin biomass available from the 1980's (Anon. 1998). Quantifying the multiplicative model is an important component in assessing the current stock status of capelin.

Capelin are an important component of the ecosystem and may be the key prey species determining the status of apex predators, such as harp seals (Phoca groenlandica) and Atlantic cod (Gadus morhua). Current estimates of harp seal consumption within the Newfoundland region indicate that consumption in 2J3KL alone was on the order of 805,856 t in 1996 (Hammill and Stenson 1997). Currently, there is no independent estimate of how important this predation pressure might be to the status of capelin and its possible impact on the marine ecosystem.

The purpose of this paper was to estimate the absolute abundance and biomass of capelin based on the mid-water IYGPT trawl used in the Pelagic Juvenile Fish Surveys carried out in 2J3KLNO 1994-1998 (Anderson et al. 1999).

Materials and Methods

The absolute abundance of capelin was estimated from the abundance of capelin caught at each station (number m^{-2}), correcting for IYGPT trawl catchability and night/day catch rate differences within three size categories of capelin: < 120 mm; 120-139 mm; ≤ 140 mm. The survey design is described in Anderson et al. (1997). These size ranges are thought to approximate the size ranges of age one, two and three year old capelin. Catchability, *q*, was based on published estimates of nekton catchability by the IYGPT trawl (Koslow et al. 1997). They estimated an overall trawl catchability coefficient of 0.14, where published estimates have typically ranged from 0.1 to 0.25. Night/day ratios were estimated for each survey and each size range of capelin where IYGPT tows were designated as either night or day depending on the start time of each tow. For stations offshore, the adjusted capelin abundances were spatially extrapolated to the area represented by each station (2.916×10^9 m^2). For the inshore (Anderson et al. 1997), the mean adjusted abundance for each inshore area was extrapolated to the total area, where was estimated using Surfer.

Biomass was estimated based on the mean weight of capelin within each of the three size groups for each survey year. These weights were based on capelin samples collected during each survey and processed in the laboratory (P. Eustace, Pelagics Section, NAFC). Biomass for a given size group, for a given year was a simple multiple of the absolute abundance by the mean weight. The total population biomass was a summation of the three length groups.

Results

Capelin were consistently caught at higher abundance during the night, compared to the day, over all size groups for all years (Table 1, Fig. 1). However, the night/day ratio varied without a consistent pattern, both among length groups and among years. The original data were examined for outliers and when these occurred, the data were removed from the night/day estimate. The night/day data indicate that there was no overall year effect across all length groups, nor was there an overall effect for any one length group.

The mean length and weights of capelin varied within the length groups among years. One year old capelin (< 120 mm) were smallest in 1994 and 1996 (i.e. the 1993 and 1995 year classes) and consequently weighed less (Table 2). There was much less variation in the mean size of the two larger length groups. However, the mean weights varied within these length groups over the five-year period, where the mid-length group (age 2) weighed more in the 1996-1998 surveys compared to the 1994-1995 surveys. In the largest length group (age 3+), capelin weighed the most during the more recent surveys in 1997 and 1998.

The absolute abundance of one year old capelin (length group 1) varied by a factor of 16.0 among years, being highest in 1994 (i.e. the 1993 year class) and lowest in 1995 (i.e. the 1994 year class) (Table 3). Over all years the absolute abundance of capelin varied from 6.6×10^{10} to 9.42×10^{11} fish; a factor of 14.3 times.

The total biomass of capelin varied by a factor of 17.4 times, from a low of 244,686 t in 1995 to a high of 4,255,848 t in 1998 (Table 3). The two largest year classes, 1993 and 1996, were largely responsible for determining the total population biomass over all age and size groups. This was particularly true for the 1996 year class that was abundant as age one capelin in the 1997 survey (< 120 mm length) and again as age two fish in the 120-139 mm length class (Table 3). In addition, the mean weight of the older, larger capelin increased in 1997 and 1998. Therefore, abundance and biomass were largely similar in trend until the 1998 survey when the abundance decreased marginally while biomass increased to the highest value in five years (Fig. 2).

The variance in our estimates of abundance and biomass due to uncertainty in the IYGPT catchability only varied by a factor of 2.5 times (Table 3). This range is considerably less than that observed in abundance and biomass over the five-year period. Based on this range in catchabilities, biomass was estimated to be as low as 137,024 t in 1995 and as high as 5,958,188 t in 1998.

It is difficult to track year-class strength among years for the three age groups, nominally regarded as age one, two and three years of age. At the larval (age 0) and one year old (age 1) stages for the 1991-1996 year classes, the ranking was: 1996 > 1993 = 1995 > 1994 > 1991 = 1992

(Anderson and Dalley 1998). The 1996 year class ranked second and first among years for age/length groups one and two, based on our estimate of absolute abundance (Table 3). Similarly, the 1994 year class ranked lowest in abundance for age/length groups one and two, but for age/length group three it ranked third. Therefore, we conclude there is some consistent in relative year-class strength among years. However, there is a lack of complete consistency among as capelin grow into the largest length groups. In addition, the magnitude of decline from age/length one to two exceeded 90% in three of four years and then it was 55%. Of greater concern was the observation that two of three year classes actually increased in abundance from age/length group two to three while in the third case abundance remained about equal.

Discussion

The two largest year classes at age one were 1993 and 1996. It is difficult to follow the 1993 year class at age two in the middle size group (120-139 mm), but the 1996 year class showed up as the largest over the five years. The absence of the 1993 year class as age two fish does not appear to be a result of slow growth and small size, such that it did not occur in the 120-139 mm length range, as the abundance of the smallest length group was the lowest observed.

The greatest source of uncertainty in our estimates appears to be the diurnal vertical migration of capelin into the trawl zone by night, 20-60 m layer, and out of it by day. There was no consistent pattern among years or among length groups. However, the high night/day ratios for a given length group within a year appear to accurately reflect the behaviour of capelin in that the ratios were determined by consistently high tows, and were not a result of one or two high catches. Previously, interannual differences in the diurnal vertical migrations of northwest Atlantic capelin were reported (Shackell et al. 1994). Diurnal catch rate differences result primarily from migration into surface waters by night and out by day, but are also due to dispersion at night and schooling by day and can vary with season (Bailey et al. 1977, O'Driscoll and Rose 1999).

The absolute abundance and biomass of capelin was previously estimated based on spring acoustic surveys, which were carried out prior to the migration and spawning of capelin. These surveys were carried out in May each year, 1985-1992 (Miller 1992). Total abundance ranged from 1.50 - 5.99 x 10^{11} capelin from 1985 to 1990, dropped by an order of magnitude to 0.30-0.31 x 10^{11} capelin in 1991 and 1992 and were estimated to be as low as 0.05 x 10^{11} capelin in May of 1996. From 1985-1990, the capelin biomass was estimated to have ranged from 2.58 - 6.96 x 10^{6} tonnes. In 1990 and 1991, biomass was estimated to have dropped to 0.11 - 0.21 x 10^{6}.

Our estimates of abundance and biomass of capelin are very similar to those estimated by the acoustic surveys, 1985-1992 (Fig. 3). (We have also plotted the results of the fall acoustic surveys (Miller 1995) for completeness although it should be noted that these results were generally not accepted as reliable indicators of stock status (Winters 1995).) A higher range of biomass, relative to abundance, estimated in the 1980's might be expected, where these surveys were conducted prior to spawning. Given that a high proportion of spawning capelin die, our survey would estimate a lower biomass, all else being equal.

The standardized biomass index of the multiplicative model ranged from 60-95 during the period 1985-1990, was approximately 75 in 1991 and 1992, and ranged from 72-118 during 1994-1997 (Anon. 1998). Therefore, the offshore estimates of abundance and biomass do not agree with the output from the multiplicative model, in that the surveys estimated higher biomass in the 1980's compared to the 1990's, whereas the multiplicative model is the reverse.

The total biomass estimated for capelin greatly exceeded the biomass of capelin consumed by harp seals in 1994, 1997 and 1998. During these years, harp seal consumption would only have amounted to 19% - 30% of the total biomass. However, in 1996 harp seal consumption would have comprised 86% of the total estimated biomass and in 1995 would have exceeded the capelin biomass. In addition, if harp seals consume primarily capelin age two and older, then the estimated consumption of capelin would exceed the available capelin biomass in all years except 1998.

There are many sources of uncertainty when trying to estimate the absolute abundance and biomass of capelin from the Pelagic Juvenile Fish Surveys, including: 1) varying catchability among years; 2) varying growth rates among years; 3) varying survival following spawning for age three and four year old capelin. There is some indication of varying catchability among years, where all three age groups ranked last in 1995. We assume that the 1994, 1993 and 1992 year classes were present in the 1995 survey, where the 1993 year class was one of the largest at ages 0 and 1 and the 1994 year class one of the smallest (Anderson and Dalley 1998). Therefore, the low total abundance and biomass estimate in 1995 should be regarded with caution.

Conversely, while the 1998 survey had the highest ranking for age/length groups two and three, these represented the 1996 and 1995 year classes which we regard as relatively strong, while the age/length one group ranked fourth. Therefore, there is no clear indication of necessarily higher catchability in the 1998 survey.

There is a clear indication that growth rate has changed in recent years, where the 1997 and 1998 surveys measured larger mean lengths for one year old capelin (length group 1) and higher mean weights for length groups two and three. The effect that varying growth rate may have on our designation of age within length group remains unknown. Similarly, varying survival following spawning will further bias our interpretation of year-class strength within the largest length group.

References

Anon. 1998. Capelin in SA2 + Div. 3KL. CSAS Res. Doc. 98/63.

Anderson, J. T., and E. L. Dalley. 1998. Year-class strength of Northwest Atlantic capelin (2J3KLNO) estimated from pelagic juvenile fish surveys in the Newfoundland region, 1991-1997. In: Capelin in SA2 + Div. 3KL. CSAS Res. Doc. 98/63. Chapter 7. pp. 114-133.

Anderson, J. T., and E. L. Dalley. 1997. Distributions and abundances of pre-recruit capelin (*Mallotus villosus*) in the northwest Atlantic (NAFO Divisions 2J3KLNO), 1991--1996. *In*: Capelin in SA2+Div. 3KL. DFO CSAS Res. Doc. 97/29. Chapter 7: 125-147.

Bailey, R. F. J., K. W. Able, and W. C. Leggett. 1977. Seasonal and vertical distribution and growth of juvenile and adult capelin (*Mallotus villosus*) in the St. Lawrence estuary and western Gulf of St. Lawrence. J. Fish. Res. Board Can. 34: 2030-2040.

Carscadden, J., B. Nakashima, and D. S. Miller. 1994. An evaluation of trends in abundance of capelin (*Mallotus villosus*) from acoustics, aerial surveys and catch rates in NAFO Division 3L, 1982-89. J. Northw. Atl. Fish. Sci. 17: 45-57.

Hammill, M. O., and G. B. Stenson. 1997. Estimated prey consumption by harp seals (*Phoca groenlandica*), grey seals (*Halichoerus grypus*), harbour seals (*Phoca vitulina*) and hooded seals (*Cystophora cristata*) in the Northwest Atlantic. NAFO SCR Doc. 97/40. Serial No. N2872. 37 p.

Koslow, J. A., R. J. Kloser, and A. Williams. 1997. Pelagic biomass and community structure over the mid-continental slope off southeastern Australia based upon acoustic and midwater trawl sampling. Mar. Ecol. Prog. Ser. 146: 21-35.

Miller, D. S. 1992. Results of an acoustic survey for capelin (*Mallotus villosus*) in NAFO Divisions 3L in 1992. NAFO SCR Doc. 92/57, Ser. No. N2110, 4 p.

1995. Results from an acoustic survey for capelin (*Mallotus villosus*) in NAFO Division 2J3KL in the autumn of 1994. P. 63-71 *In*: Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 95/70.

O'Driscoll, R. L., and G. A. Rose. 1999. Seasonal changes in abundance, distribution, and vertical migration of capelin in Placentia Bay. *In*: Capelin in SA2 + Div. 3KL. CSAS Res. Doc. 99/xx. P. xxx-xxx.

Shackell, N. L., J. E. Carscadden, and D. S. Miller. 1994. Diel vertical migration of capelin (Mallotus villosus) and its effect on acoustic estimates of density. **In**: Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 94/18. 109-126.

Winters, G. H. 1995. Interaction between timing, capelin distribution and biomass estimates from the Div. 2J3K capelin acoustic survey. P. 167-192. In: Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 95/70.

Table 1. Ratio of night to day capelin densities (number m^{-3}) for each year and each size (age) group, where age 1 is < 120 mm, age 2 is 120-139 mm, and age 3 is ≥ 140 mm.

Year	Age 1	Age 2	Age 3
1994	9.62	12.03	4.10
1995	2.96	7.96	3.68
1996	53.38	17.20	4.91
1997	2.15	1.65	14.96
1998	4.26	25.42	49.24

Table 2. Mean length (mm) and weight (g) of capelin within three size categories sampled in the Pelagic Juvenile Fish Surveys, 1994-1998.

Year	Length			Weight		
	< 120 mm	120-139 mm	≥ 140 mm	< 120 mm	120-139 mm	≥ 140 mm
1994	92.6	127.6	152.1	2.9	7.6	12.5
1995	99.7	127.7	142.0	3.2	7.3	8.8
1996	90.9	131.1	149.0	2.5	8.4	11.1
1997	97.9	129.9	149.5	3.5	8.9	14.9
1998	101.9	129.3	149.4	3.7	8.3	15.4

Table 3. Absolute abundance and biomass (t) estimates for capelin length groups 1-3 caught in the IYGPT trawl during annual Pelagic Juvenile Fish Surveys in 2J3KLNO.

	Q=0.14							
Year	Group 1		Group 2		Group 3		Total Pop	Total Bio
	Population	Biomass (t)	Population	Biomass (t)	Population	Biomass (t)		
1994	9.20E+11	2,669,112	1.94E+10	147,247	2.67E+09	33,446	9.42E+11	2,849,806
1995	5.76E+10	184,306	7.65E+09	56,130	4.81E+08	4,249	6.57E+10	244,686
1996	3.19E+11	810,155	5.63E+09	47,444	7.54E+09	83,668	3.32E+11	941,267
1997	6.18E+11	2,151,376	2.87E+10	254,292	2.00E+10	296,534	6.67E+11	2,702,202
1998	2.65E+11	969,562	2.79E+11	2,304,168	6.37E+10	982,118	6.07E+11	4,255,848
						Mean	5.23E+11	2,198,762

	Q=0.10							
Year	Group 1		Group 2		Group 3		Total Pop	Total Bio
	Population	Biomass (t)	Population	Biomass (t)	Population	Biomass (t)		
1994	1.29E+12	3,736,757	2.71E+10	206,146	3.74E+09	46,825	1.32E+12	3,989,728
1995	8.06E+10	258,029	1.07E+10	78,582	6.74E+08	5,949	9.20E+10	342,561
1996	4.47E+11	1,134,217	7.89E+09	66,422	1.06E+10	117,135	4.65E+11	1,317,774
1997	8.65E+11	3,011,926	4.02E+10	356,009	2.79E+10	415,148	9.34E+11	3,783,082
1998	3.71E+11	1,357,386	3.90E+11	3,225,836	8.92E+10	1,374,965	8.50E+11	5,958,188
						Mean	7.32E+11	3,078,266

	Q=0.25							
Year	Group 1		Group 2		Group 3		Total Pop	Total Bio
	Population	Biomass (t)	Population	Biomass (t)	Population	Biomass (t)		
1994	5.15E+11	1,494,703	1.08E+10	82,458	1.49E+09	18,730	5.28E+11	1,595,891
1995	3.23E+10	103,212	4.28E+09	31,433	2.69E+08	2,380	3.68E+10	137,024
1996	1.79E+11	453,687	3.16E+09	26,569	4.22E+09	46,854	1.86E+11	527,109
1997	3.46E+11	1,204,770	1.61E+10	142,403	1.12E+10	166,059	3.73E+11	1,513,233
1998	1.48E+11	542,955	1.56E+11	1,290,334	3.57E+10	549,986	3.40E+11	2,383,275
						Mean	2.93E+11	1,231,307

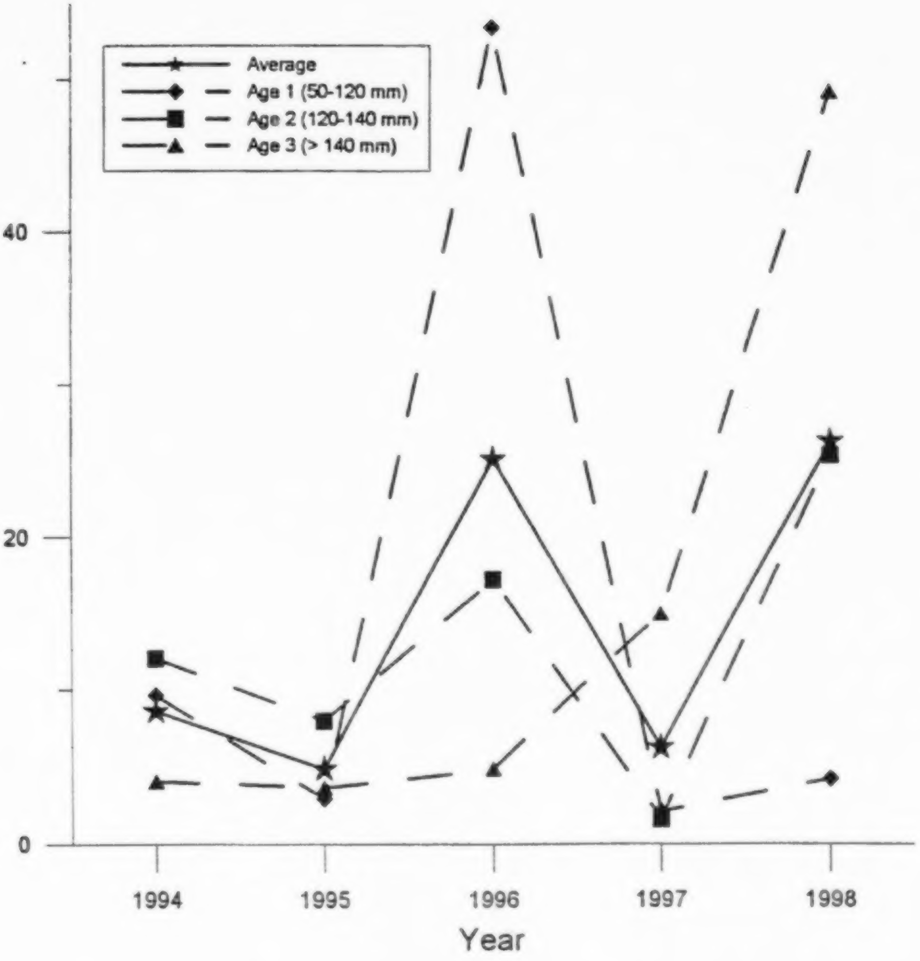


Figure 1. Day versus night abundance ratios for different age/size groups for each survey year. The average is for all age/size groups each year.

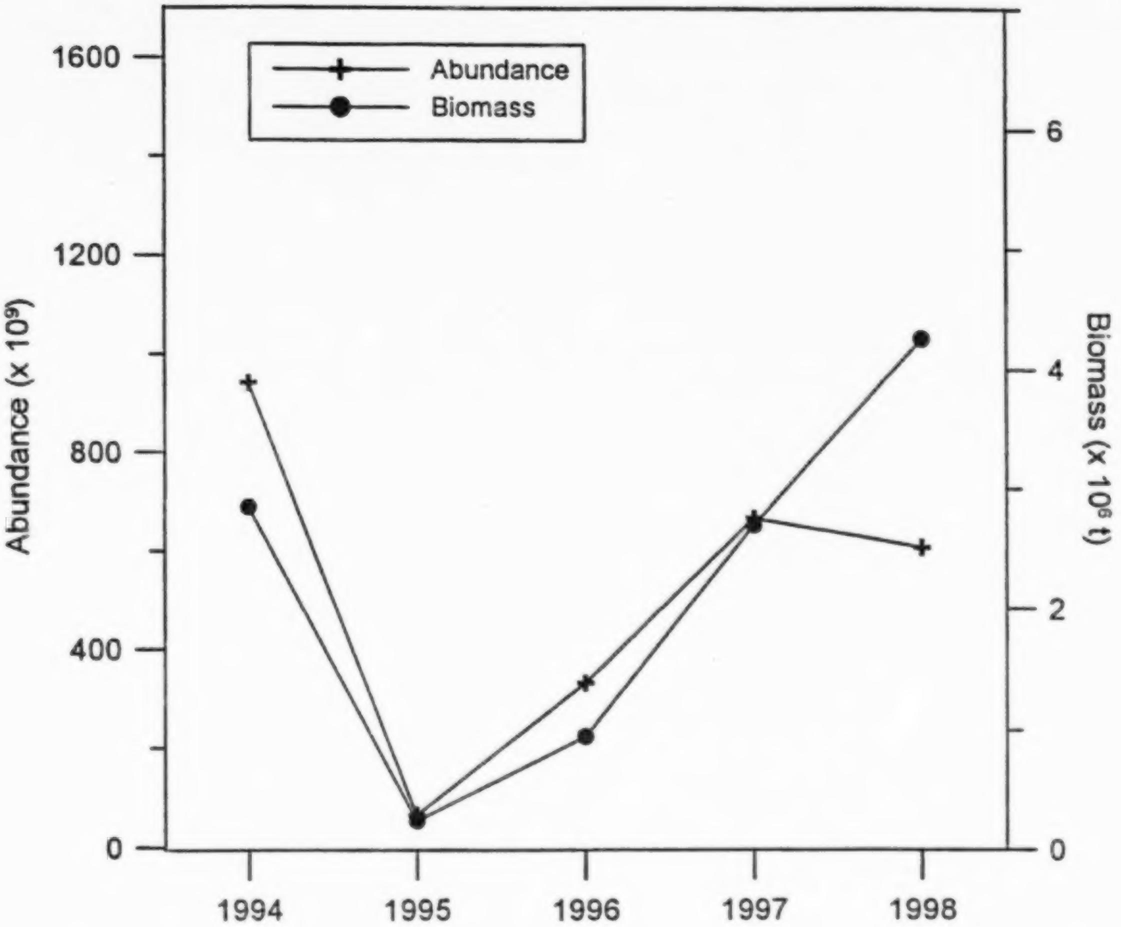
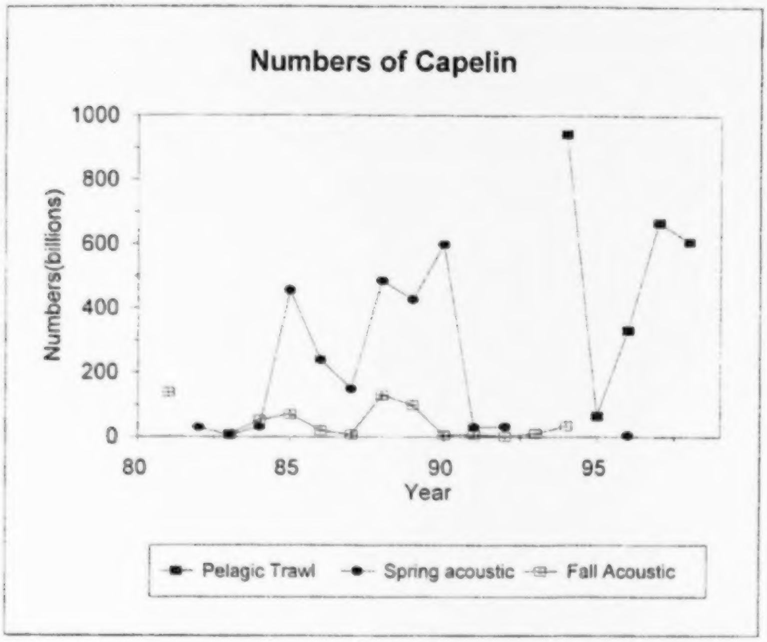


Figure 2. Absolute abundance and biomass of capelin in the North-west Atlantic (2J3KLNO), as estimated from the Pelagic Juvenile Fish Surveys, 1994-1998.



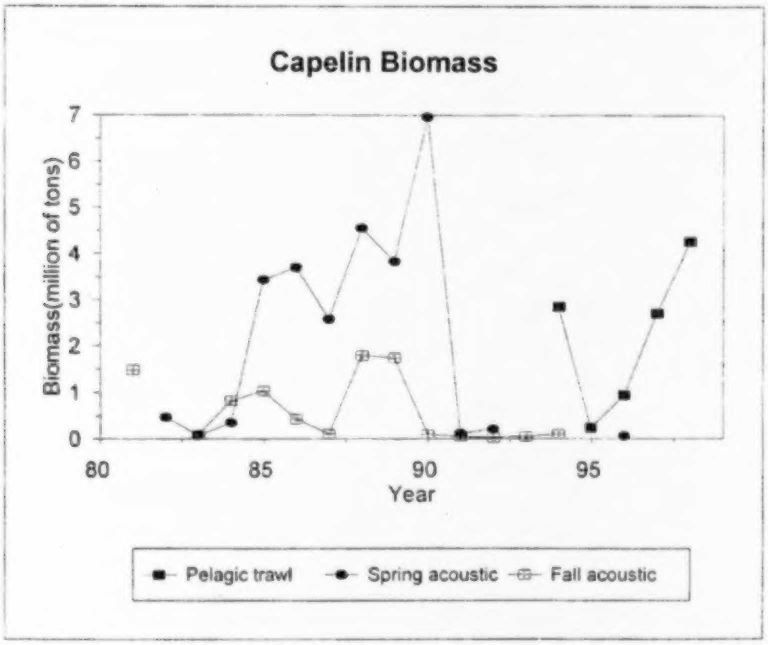


Fig. 3. Estimates of capelin abundance (a) and biomass (b) based on acoustic surveys in spring (1982-92, 1996) and autumn (1981-94) and pelagic trawls surveys (1994-98), in the Newfoundland Region.

Year-Class Strength of Northwest Atlantic Capelin (2J3KLNO) Estimated at the Larval Stage and Age One Based on the Pelagic Juvenile Fish Surveys, 1994-1998

by

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Introduction

Research trawl surveys to estimate the year-class strength of capelin within NAFO Divisions 2J3KLNO have been carried out since 1991 (Anderson and Dalley 1995, 1996, 1997, 1998). Two gear types are used to sample capelin in the upper water column, for the larval stage (0-Group; 3-50 mm) and one year old (1-Group, 50-119 mm). The survey is carried out at the end of August and early September, timed to sample pelagic juvenile cod before they settle to the bottom, and larval capelin released from beach and bottom sediments.

The purpose of this paper is to report on the abundance and distribution of larval and juvenile capelin from the 1998 survey, and to compare these results to the previous surveys carried out 1994-1997. Materials and methods used in this project have been previously described by Anderson and Dalley (1995, 1996, 1997).

Results and Discussion

Survey

The survey was conducted from August 24 to September 10, 1998 (Table 1). In 1998, 132 stations were sampled with the bongo and IYGPT samplers. These stations covered the inshore areas along the northeast coast of Newfoundland and six offshore areas over the Northeast Newfoundland Shelf and on the Grand Banks (Fig. 1). Survey stations in the outer most areas along the shelfbreak were not occupied due to time constraints. Bonavista Bay was not sampled in 1998 due to the early recall of the research ship Teleost.

Abundance Indices Ages 0 and 1 Year

Previously, we have reported the abundance of larval capelin (0-group) based on the bongo samples using three different indices. The purpose of the different indices was to extend the time series of observations to the 1991-1993 period, before the two ship surveys began in 1994. It was rationalized that the majority of capelin observed during the 1990's were distributed within the area surveyed by the single ship during 1991-1993. We now have five years of data based on the two-ship survey which covers a much wider geographic distribution. Comparisons of year-class indices during the last five years, 1994-1998, demonstrated a linear and highly significant relationship between the Weighted Index Area index (WIA) and both the "common area" and "non-zero catches" indices (Table 2, Fig. 2). The best comparison of the WIA index was with the index for the common area, but both regressions have a high degree of predictive power.

Similarly, we compared the index of abundance at the larval stage to that estimated at age one based on the WIA index. There was a highly linear and statistically significant relationship estimating year-class strength between ages (Table 2, Fig. 3). Both indices estimate the year-class abundance ranked as: 1996 > 1995 > 1997 > 1994.

We note that Bonavista Bay was not sampled in 1998, due to the early recall of the research ship Teleost. Previously, Bonavista Bay has been an important index area for capelin at both the larval stage and at age one. We compared the ratio of abundance measured in Bonavista Bay to the total for the other inshore areas (Conception Bay, Trinity Bay, Notre Dame Bay, White Bay) for the previous four survey years, 1994-1997. For larvae, the mean ratio was 0.183 (Std Dev 0.0628, CV 34.4%). We felt this ratio was stable enough over the previous four years that it could be used to estimate the abundance of capelin larvae in the Bonavista Bay Index Area for 1998. Therefore, we have used this ratio in the estimate for the WIA (Table 3). Compared to the overall (i.e. total) estimate where Bonavista Bay was left not sampled, the predicted value increased the total WIA for 1998 by 7.0%. This increase had the effect of increasing the 1998 larval abundance index to a value similar to the 1997 year-class.

For age one capelin, the ratio of Bonavista Bay to the other inshore areas averaged 19.85 (Std Dev 38.50, CV 194%, range 0.23-77.6). The huge range among years precludes predicting the abundance of one-year-old capelin in the Bonavista Bay Index Area in 1998 based on the abundance observed in the other inshore areas. If such an estimate is used it would result in an increase to the total WIA estimate of 37.9%. We felt this increase based on such a highly variable ratio was not justified. Therefore, our estimate of year-class strength for the 1997 year-class at age one is biased low due to the absence of any data from Bonavista Bay in 1998. However, while the degree of this bias remains unknown, it is apparent from the comparison of the WIA indices at the larval stage compared to age one that the abundance of one year old capelin in Bonavista Bay in 1998 may have been relatively low (Fig. 3).

The year-class strength estimate based on larval capelin increased from 1994 to a peak in 1996 (Fig. 4). During 1997 and 1998 year-class strength has been less than 1995 but greater than 1994. At age one, year-class strength was highest in 1993, reached a minimum in 1994 and increased to relatively high values for the 1996 year class (Fig. 5). The estimate for the 1997 year-class at age one based on the 1998 survey is clearly biased low due to the absence of abundance data from Bonavista Bay.

Distribution of Larvae and Juveniles and Adults

Capelin larvae were distributed along the northeast coast of Newfoundland, as in previous years (Fig. 6). However, in 1998 capelin larvae were observed off the coast of Southern Labrador and on the Southeast Shoal of the Grand Bank for the first time. These distributions indicate that capelin spawning occurred further to the north and south in 1998 than in the previous four years of the survey. Spawning on the Southern Grand Bank previously occurred during August (Frank and Carscadden 1989) as did spawning in Southern Labrador (B. Nakashima, pers. comm.). Large capelin larvae were also observed dispersed onto the northern portion of the Grand Bank in 1998.

Juvenile capelin, age one, occurred extensively on the southern portion of the Northeast Newfoundland Shelf and on the Northern Grand Bank in 1998, as observed in previous years (Fig. 7). In 1998, juveniles were distributed off Southern Labrador more abundantly than in previous years.

Adult capelin in late spawning condition were observed on the Southern Grand Bank in 1998 for the first time.

Size of Capelin

Mean length of capelin in the bongos was 11.7 mm, range 3-27 mm, which was very similar to mean lengths of 8.9-10.7 mm, 1994-1997.

Mean length of age one capelin in 1998 (i.e. the 1997 year-class) was 96.2 mm, range 51-119 mm (Fig. 8). This mean length was approximately in the middle of the range of mean lengths measured at age one for the 1993-1996 year-classes (range 84.6-103.1 mm). The ranking of mean length of capelin measured at age one for the 1994-1997 year-classes is: 1994 > 1997 > 1995 = 1996 > 1993.

References

Anderson, J. T., and E. L. Dalley. 1995. Distribution and abundances of pre-recruit capelin (Mallotus villosus) in the Newfoundland region, 1991-94. In: Capelin in SA2 + Div. 3L. Chapter 9. DFO Atl. Fish. Res. Doc. 95/70. P. 133-145.

Anderson, J. T., and E. L. Dalley. 1996. Distribution and abundances of pre-recruit capelin (Mallotus villosus) in the Newfoundland region, 1994 and 1995. In: Capelin in SA2 + Div. 3L. Chapter 14. DFO Atl. Fish. Res. Doc. 96/90. P.185-199.

Anderson, J. T., and E. L. Dalley. 1997. Distribution and abundances of pre-recruit capelin (Mallotus villosus) in the Newfoundland region, 1991-1996. In: Capelin in SA2 + Div. 3L. Chapter 7. DFO Canadian Stock Assessment Secretariat Res. Doc. 97/29. P. 125-147.

Anderson, J. T., and E. L. Dalley. 1998. Year-class strength of northwest Atlantic capelin (2J3KLNO) estimated from pelagic juvenile fish surveys in the Newfoundland Region, 1991-97. In: Capelin in SA2 + Div. 3KL. CSAS Res. Doc. 98/63. P. 114-133.

Frank, K. T., and J. E. Carscadden. 1989. Factors affecting recruitment variability of capelin (*Mallotus villosus*) in the Northwest Atlantic. J. Cons. int. Explor. Mer 45: 146-164.

Table 1. Summary of Pelagic Juvenile Fish Surveys conducted, 1994-1998. Bongo–bongo plankton sampler; IYGPT–International Young Gadoids Pelagic Trawl. DoY–refers to the calendar day of the year; Start, End and Mid refer to the starting, ending and middle day of the year for each survey. The numbers below each gear type list the number of stations sampled each year by each gear type.

Year	Ship-Trip	Dates	DoY Start	DoY End	DoY Mid	Bongo	IYGPT
1994	TEM157/GAD247	22 Aug–3 Sep	234	246	241	99	99
1995	TEM175/TEL018	5 Sep–22 Sep	248	264	257	139	139
1996	TEM193/TEL034	19 Aug–6 Sep	231	249	241	147	147
1997	TEM210/TEL050	11 Aug–29 Aug	223	241	233	148	148
1998	TEM226/TEl069	24 Aug–10 Sep	236	253	244	132	132

Table 2. Summary of linear regressions comparing different abundance indices. Non-Zero refers to the mean standardized catch rate (number m-3) for all positive catches each year. Common Area refers to the mean standardized catch rate (number m-3) for a commonly sampled area and includes null catches. WIA refers to the Weighted Index Area method where "0" is larval capelin and "1" is age one juvenile capelin.

Variables	Regression	df	F-Value	P-Value	r^2
Non-Zero (Y) vs WIA 0 (X)	Y = -70.03 + 0.0028X	4	13.3	0.01	0.930
Common Area (Y) vs WIA 0 (X)	Y = 3.75 + 0.0017X	4	170.0	0.001	0.994
Age 1 WIA (Y) vs Age 0 WIA (X)	Y = -952.4 + 0.0285X	4	340.1	0.001	0.997

Table 3. Abundance indices for Northwest Atlantic capelin (NAFO Divisions 2J3KLNO) based on the two-ship surveys, 1994-1997 using the Weighted Index Area method for non-transformed data (number $10^3 m^{-3}$). * - indicates estimated value see text

	NOM3	10^5								
	Sampling Year 1994		Sampling Year 1995		Sampling Year 1996		Sampling Year 1997		Sampling Year 1998	
Area	0-Group	1-Group	0-Group	1-Group	0-Group	1-Group	0-Group	1-Group	0-Group	1-Group
Inshore										
CB	7865.39	2151.19	27825.12	8.62	59170.22	0.42	18101.30	15.18	18203.82	14.64
TB	3797.05	258.49	13760.88	8.46	35682.76	24.29	13363.79	1676.25	1801.22	23.72
BB	4615.81	1067.86	13439.82	7.74	37952.82	3216.28	17749.19	3079.55	11830.7*	
NDB	18803.24	45.93	19478.60	234.63	45499.36	12.04	17034.89	2.00	30448.79	30.14
WB	17589.24	34.44	7671.55	1.58	57695.52	4.70	23459.91	1022.81	14383.76	14.12
SUM	52670.73	3557.91	82175.97	261.03	236000.68	3257.73	89709.08	5795.79	76668.29	82.62
Offshore										
HB			0.00	0.00	0.00	0.00	0.00	0.00	4404.30	0.00
ISN			4311.18	0.00	0.00	0.16	286.38	52.80	6041.34	1.68
ISS	28081.33	50.95	34173.79	14.64	196751.14	10.82	76000.98	1.34	65324.17	68.54
BIBI			0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00
BIBO										
FIBI			5805.14	8.31	3201.03	1798.45	0.00	3.32	5560.74	408.08
FIBO										
NGB	9181.50	16834.73	143567.73	718.82	63705.86	1675.37	12943.71	7392.86	11740.84	3922.34
SA	8064.32	219.38			14021.44	16.95	21928.66	1126.22		
SGB	53.28	812.65	973.80	341.09	0.00	0.00	340.81	0.62	16548.69	59.25
NOSE					0.00	606.74	0.00	51.78	776.38	1638.66
TAIL										
SGBO										
WD										
SUM	37316.11	17698.33	188831.64	1082.86	263658.03	3484.80	89571.88	7451.14	105215.78	4459.87
TOTAL	89986.84	21256.24	271007.61	1343.89	499658.71	6742.53	179280.96	13246.93	181884.07	4542.49

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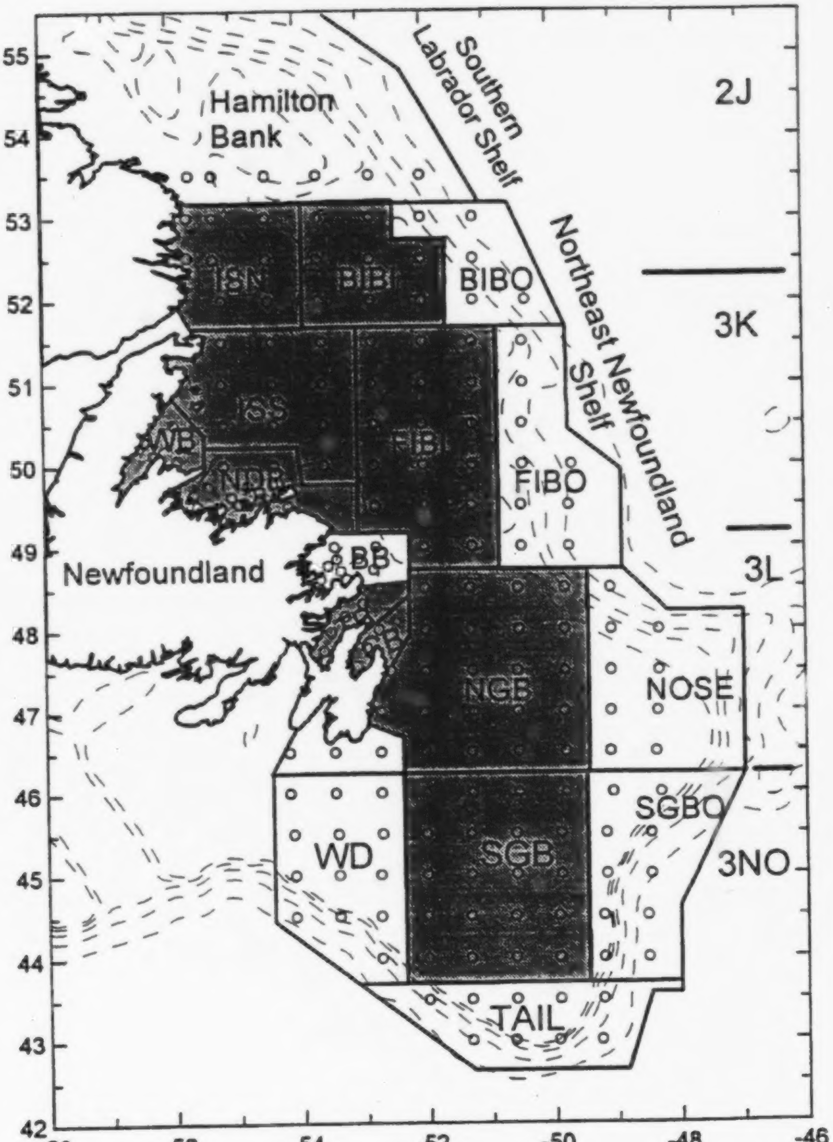
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BIBO
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Newfoundland
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Figure 1. Pelagic Juvenile Fish Survey area, showing sampling locations (indicated by 'o') and Index Areas in 1998. The shaded areas represent the Index Areas used in the calculation of annual abundance indices. See text for explanation of areas.

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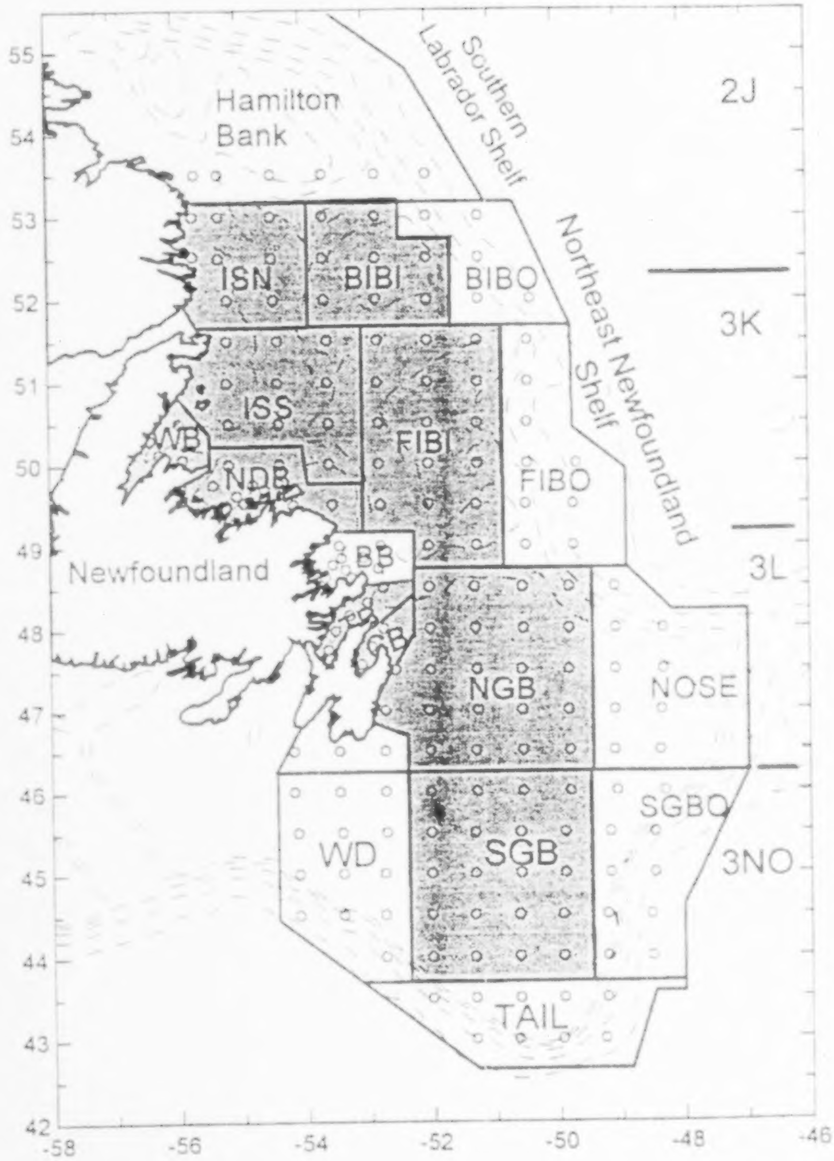
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Northeast Newfoundland Shelf
3K
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WB
NDB
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Figure 1. Pelagic Juvenile Fish Survey area, showing sampling locations (indicated by 'o') and Index Areas in 1998. The shaded areas represent the Index Areas used in the calculation of annual abundance indices. See text for explanation of areas.

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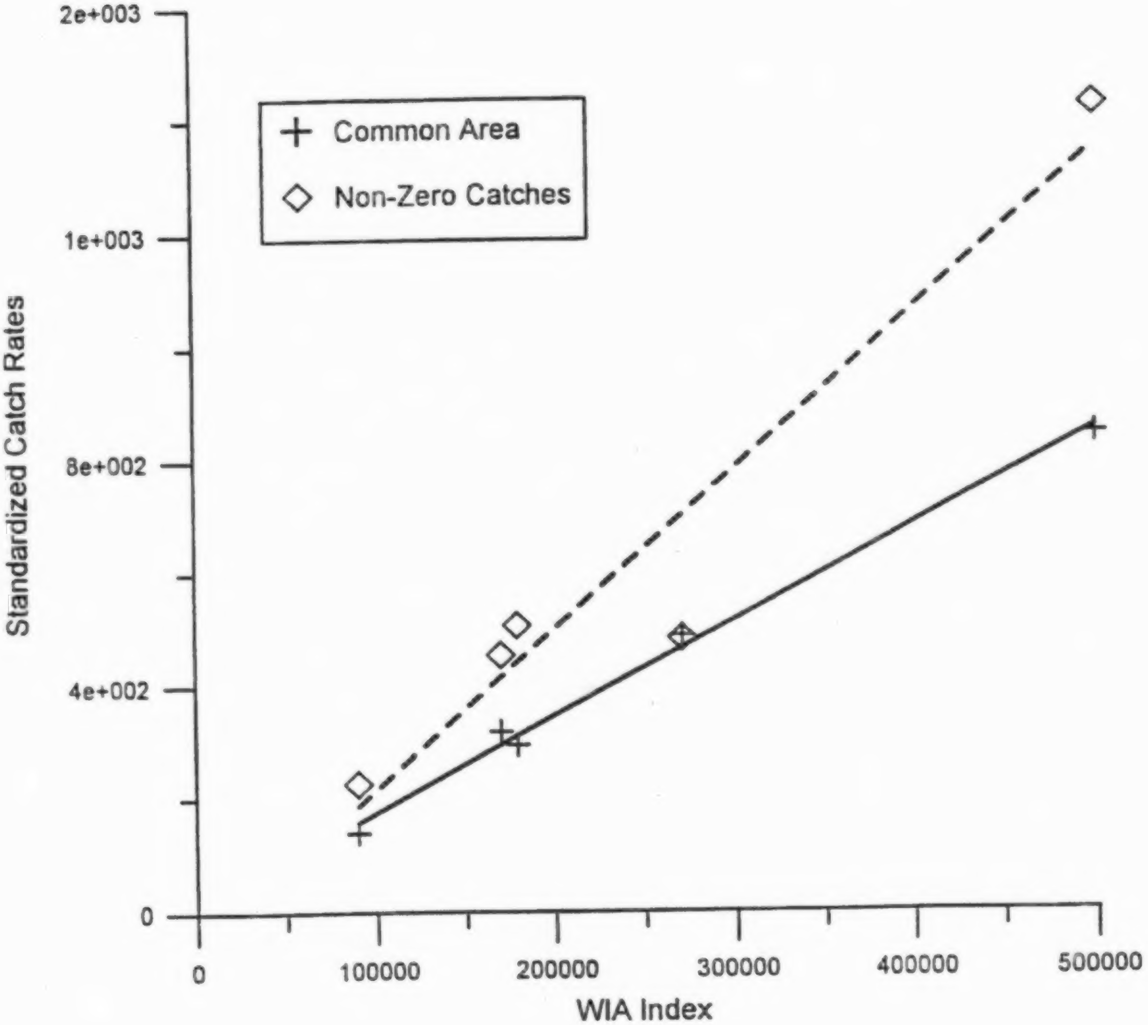

Figure 2. Comparison of different indices of larval capeln (0-group) abundance. The Weighted Index Areas index (WIA) is compared to two different standardized catch rate indices used in previous analyses.

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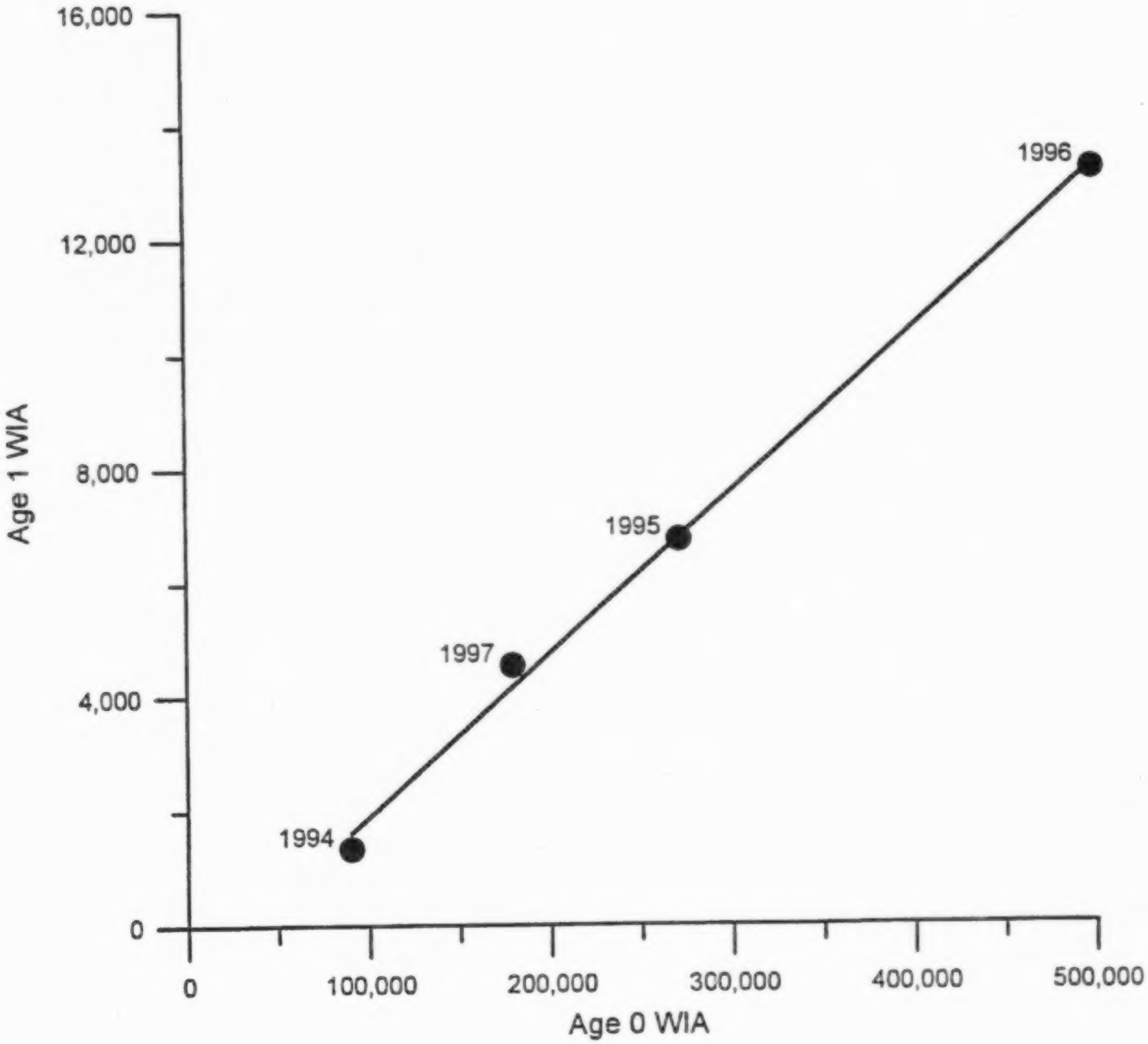

Figure 3. Comparison of the Weighted Index Area (WIA) indices for the 1994-1997 year classes at the larval stage (0-group) and at age one (1-group).

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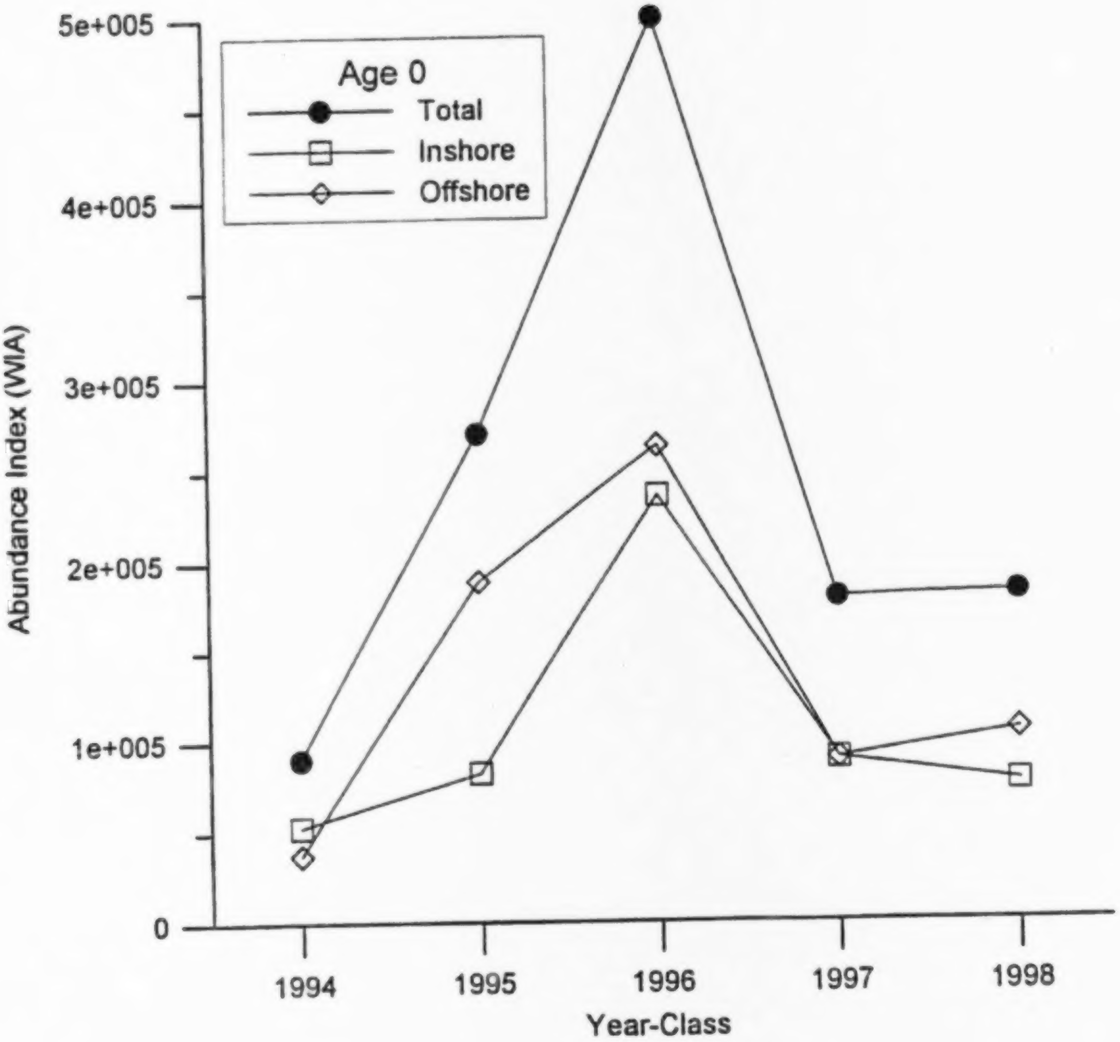

Figure 4. Abundance indices for larval (0-group) capelin based on the Weighted Index Area (WIA) method for the 1994-1998 year-classes.

File: WIA_0Grp.grf

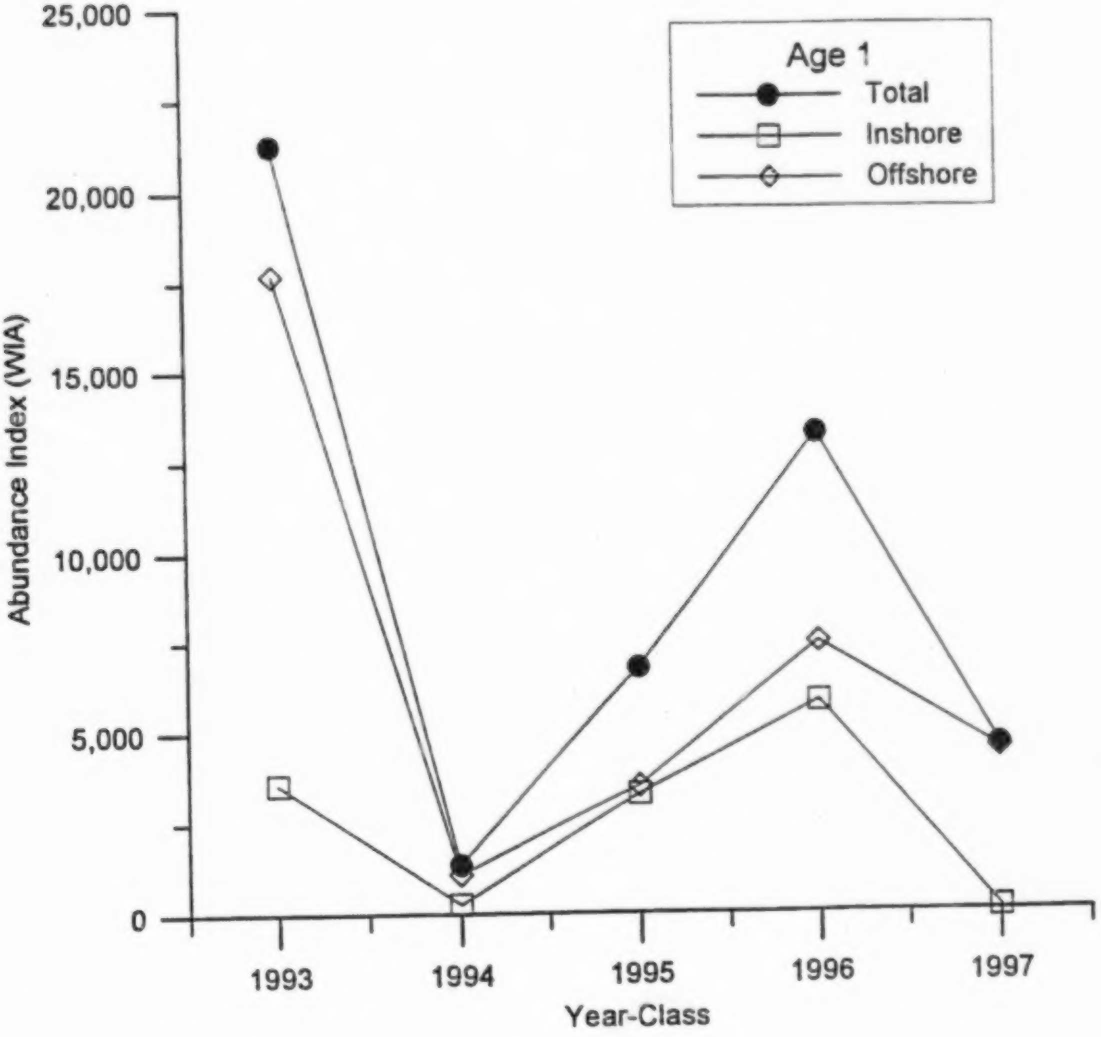

Figure 5. Abundance indices for age one (1-group) capelin based on the Weighted Index Area (WIA) method for year-classes 1993-1997.

File: WIA_1Grp.grf

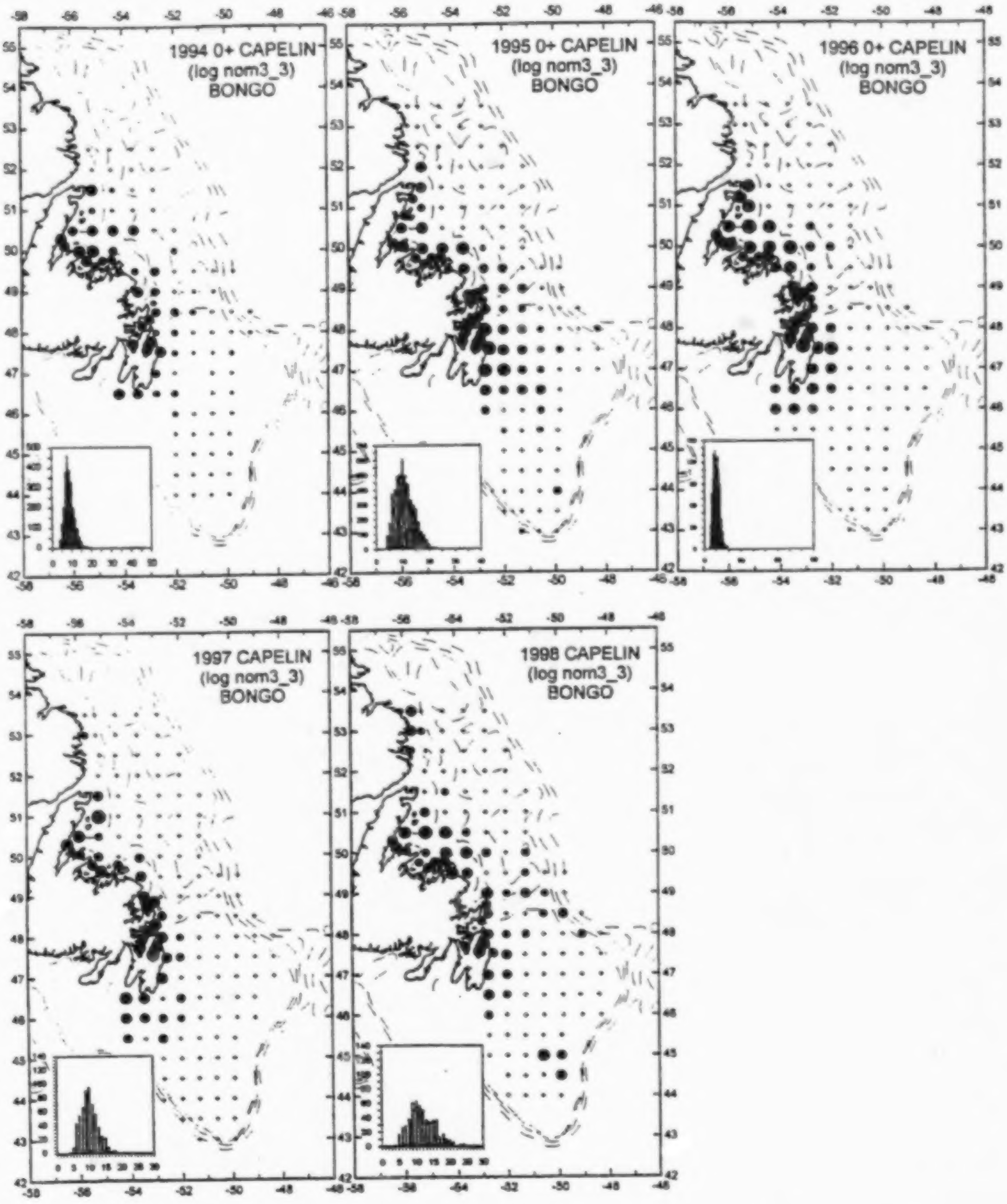
1994 0+ CAPELIN
(log nom3_3)
BONGO
1995 0+ CAPELIN
(log nom3_3)
BONGO
1996 0+ CAPELIN
(log nom3_3)
BONGO
1997 CAPELIN
(log nom3_3)
BONGO
1998 CAPELIN
(log nom3_3)
BONGO

Figure 6. Distribution of larval capelin sampled by the bongo sampler in 1998. Abundance (log_10 number/m3) at each station is represented by an expanding symbol. Crosses (+) represent stations where capelin were not caught.

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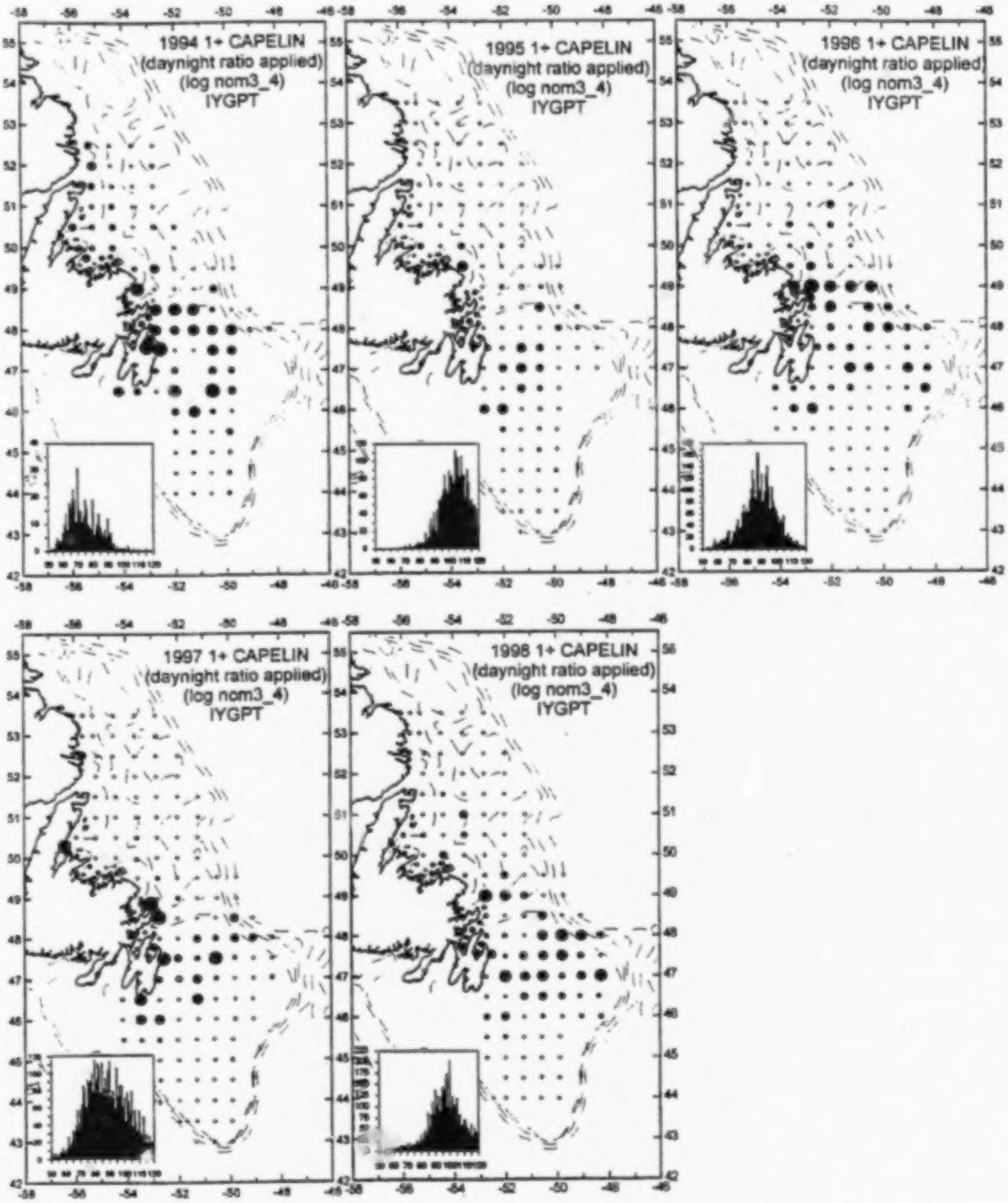
1994 1+ CAPELIN
(daynight ratio applied)
(log nom3_4)
IYGPT
1995 1+ CAPELIN
(daynight ratio applied)
(log nom3_4)
IYGPT
1996 1+ CAPELIN
(daynight ratio applied)
(log nom3_4)
IYGPT
1997 1+ CAPELIN
(daynight ratio applied)
(log nom3_4)
IYGPT
1998 1+ CAPELIN
(daynight ratio applied)
(log nom3_4)
IYGPT
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Figure 7. Distribution of one year old capelin sampled by the IYGPT trawl in 1998. Abundance (log_10 number/m) at each station is represented by expanding symbols. Crosses (+) indicate stations where capelin were not caught.

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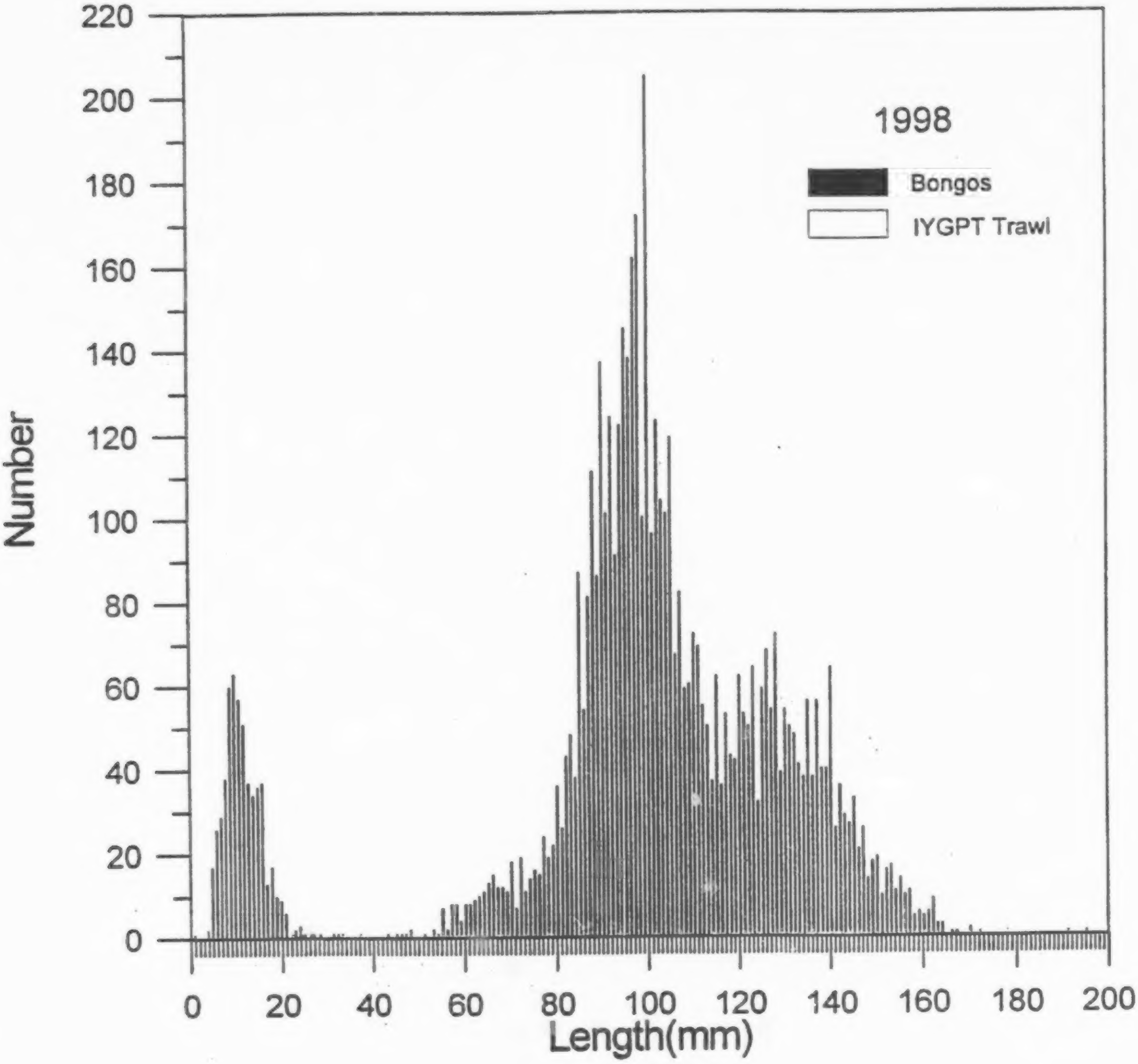

Figure 8. Length (mm) frequency distribution of capelin sampled by the bongo and IYGPT samplers in 1998.

Estimates of Consumption of Capelin

by

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Introduction

In the northern hemisphere, capelin (Mallotus villosus) plays a dual role, being both an important commercial and forage species. In the Northwest Atlantic, capelin appear to be key components in the diet of several commercial species of marine fish as well as marine mammals and seabirds. There are many feeding studies on various predators which list capelin as a key diet component. Several authors (e.g. Winters and Carscadden 1978, Lilly et al. 1991, Hammill and Stenson 1997) have taken the results of feeding studies and using population and/or production estimators, have calculated the total consumption of capelin by the predator of interest.

During the early 1970's, an offshore capelin fishery was rapidly developing and as a result, knowledge of capelin abundance was necessary for management. Estimates of capelin consumption by some major predators were calculated for that time period and these estimates were compared to those calculated for earlier periods, when predator stocks were much higher. It was assumed that the decline in total capelin consumption represented the potential biomass of capelin available to a commercial fishery (Winters and Carscadden 1978). This method was recognized as a crude technique to identify potential fishable biomass and several caveats to that effect were provided by the authors (Winters and Carscadden 1978), nevertheless the information was used as an early tool to provide scientific advice to management (Carscadden 1984).

In the intervening two decades, there has been a considerable amount of research, including food and feeding studies on capelin predators, estimation of total consumption of capelin and direct estimation of capelin abundance. Scientific advice to managers during the 1980's tended to be based on direct measurements of capelin abundance from acoustic surveys as well as other indices of capelin abundance. However, during the 1990's, the provision of advice on capelin stock status has proven problematic. (It is not the intent to review the problems nor the potential causes since these have been discussed extensively in several assessment and other documents. For more information the reader should consult Anon. (1994, 1995, 1996, 1997, 1998a). In the 1998 assessment of stock status (Anon. 1998a) considerable concern was expressed about the indices used to assess the status of the Div. 2J3KL capelin stock, the multiplicative model used in the assessment and the fact that the scientific assessment was optimistic compared to the more pessimistic view of fishermen about capelin stock status. The problems in assessing capelin stock status coincide with changes in capelin biology (Carscadden et al. 1997, Frank et al. 1996, Nakasima 1996) and other changes in the ecosystem. Biological changes in the ecosystem include changes in abundance in other forage species (shrimp and crabs) as well as predator species (cod, seals, Greenland halibut).

With the changes in predator abundance and the unresolved differences in perception of capelin abundance, the time seems appropriate to revisit some of the earlier consumption calculations and update them. Although these estimates should be treated with caution in a management context, they may provide insight into the biological changes in the Newfoundland Shelf ecosystem. In this paper, I concentrate on cod, seals, and Greenland halibut simply because of the availability of previous consumption estimates which permits comparison to current estimates. However some additional information is provided for other predators.

Cod

There have been several estimates of consumption of capelin by cod in the Div. 2J3KL area (Turuk 1978, Minet and Perodou 1978, Winters and Carscadden 1978, Lilly et al. 1981).

All of these studies used values of consumption expressed as amount of capelin consumed annually per unit weight of cod. In addition, Lilly et al. (1981) used a production method but in this document I will use only the former method. Lilly et al. (1981) reviewed the method of estimation for each of the three earlier papers so only the salient points will be made here.

Turuk's (1978) data were collected during 1973 and 1976 from Div. 2GHJ and 3LNO (nothing from Div. 3L) and she combined estimates of feeding rate with observations on stomach contents. The sources of the feeding rates are unknown and one of her corrections is inappropriate and apparently incorrectly calculated (Lilly et al. 1981), nevertheless, Lilly et al. (1981) derived an average value of 2.38 for the weight of capelin eaten per unit of cod in Div. 2J3K and 3NO.

Minet and Perodou (1978) estimated that the average cod consumed 0.76 to 1.27 times its weight of capelin annually. These values were based on observed mean weights of capelin in the meal of an average cod, published gastric evacuation rates and the assumption that cod prey on capelin for only half the year (summer and winter). Because of the latter assumptions, the range is considered a minimum estimate since there is some predation during the other seasons and the inshore summer predation was not included (Lilly et al. 1981).

Winters and Carscadden (1978) used an indirect method to calculate consumption. This calculation involved several assumptions including proportion of capelin in the annual diet of cod (= 0.32) from Campbell and Winters (1973), total mortality (Z), gross growth efficiency (K), the production-biomass rate (P/B) equal to Z. They calculated that the annual consumption per unit weight of cod was 0.64 but increased this to 1.0 on the belief that cod abundance was lower during the period of interest (late 1960's).

These studies provide a range of estimates of capelin consumed per unit weight of cod. We can then perform a series of calculations similar to that performed by Lilly et al. (1981), that is, provide a range of capelin estimates consumed by cod during different time periods, using biomass estimates of cod and the multipliers discussed above. I have used 2+ biomass (P. Shelton, pers. comm.). Clearly, the consumption estimates will track the biomass estimates of cod, however, the exercise does provide a range of capelin consumption based on the available data (Fig. 1). The basic assumption in this exercise is that the amount of capelin consumed per unit biomass of cod is fixed over time and does not change with changes in abundance or any other biological factor (distribution, migration patterns, mean size) of either cod or capelin. It should also be emphasized that the exact trajectory of cod biomass is very uncertain during the late 1980's and early 1990's when the estimates from the sequential population analysis are not closely linked to other indicators of abundance (P. Shelton, pers. comm.). However, the northern cod stock has been under fishing moratorium since 1992 because the stock size was extremely low. Therefore, estimates from 1992 to 1997 must be assumed to reasonably reflect the status of the cod stock, especially compared to historical estimates. At such low stock sizes (estimates from 1992 to 1997 range from a low of 4000 t to a high of 50,000 t, with an average of 14,000 t) total annual consumption must also be low relative to historical consumption.

With the cod stock so low in the mid 1990's it is interesting to examine historical consumption estimates and calculate the overall decline in capelin consumption by northern cod. I have chosen three years to illustrate the extent of the decline in consumption; 1962, the earliest available cod estimate and when the cod stock was high relative to the present; 1981, the year that Lilly et al. (1981) summarized the cod consumption data and a time when cod biomass was increasing; and, 1997, during the present period of extremely low abundance. The actual consumption estimates using the different consumption factors clearly demonstrate the decline in capelin consumption by cod (Table 1). During the early 1960's, capelin consumption might have ranged between 2 to 6.5 million tons of capelin, depending on the factor. By 1981, capelin consumption had probably declined such that capelin consumption could have ranged between 0.7 to 2.2 million tons, again depending on the factor used. With the recent collapse of the cod stock, annual capelin consumption by cod may be below 20,000 tons. If we adopt a factor in the middle of the range, say 1.0 -1.27, it is possible that cod consumption of capelin has decreased by approximately 1.0 million tons between the early 1980's, when the northern cod stock was increasing after the 1970's decline, and the present historical low cod abundance.

Greenland Halibut

Although Greenland halibut were known to prey on capelin (Lear 1969), they were not always highlighted as an important predator (Bowering and Lilly 1992), perhaps because they never enjoyed the historical importance as a commercial species. However, Bowering and Lilly (1992) provided estimates of capelin consumption by Greenland halibut of 105,000 t, 154,000 t and 208,000 t during 1981, 1982, and 1984 respectively in Div. 2J3K. The average of the three estimates is 156,000 t of capelin consumed. Although the authors considered the estimates conservative, it is clear that Greenland halibut were consuming considerable quantities of capelin.

The estimates were calculated by measuring total weight of capelin in the stomachs of Greenland halibut at the time of sampling and converting this to a daily feeding rate and daily consumption rate using observations from the Bering Sea. Annual consumption of capelin was then estimated by assuming that Greenland halibut feed on capelin for six months of the year. Bowering and Lilly (1992) provided several ways in which their estimates might be improved, one of which was a better knowledge of the catchability of the trawl. They assumed that the trawl catchability was 1.0 but noted that if the value were less than one, then both the population estimates of Greenland halibut and consumption estimates of capelin would be higher. This was well illustrated between 1981 and 1982, when the mean catch per tow of Greenland halibut increased, resulting in an increase in the total weight of prey in the stomachs.

Since the calculation of the consumption estimates (Bowering and Lilly 1992), the standard bottom trawl gear has changed to Campelen gear with higher catch rates. Thus, this should result in higher estimates of capelin consumption and the following discussion attempts to update those consumption estimates based on the new trawl estimates of abundance.

Bowering and Lilly (1992) reported that the major consumers of capelin were Greenland halibut in the 30-59 cm length range. For example, of 1755.3 tons of capelin eaten at the time of sampling in 1982, 1465.8 tons (84%) were eaten by Greenland halibut in that length range. These lengths correspond approximately to ages 4-10 (p. 604 in Bowering 1983) and these ages were used in the following comparisons. Conversions of abundance from the old trawl gear to the new trawl gear derived from comparative trawling experiments were length-based (Warren 1996) and these conversions were applied in subsequent assessments (Brodie et al. 1997). I compared the abundance estimates for ages 4-10 from Campelen estimates (Table 17, Brodie et al. 1997) to earlier unconverted estimates (Tables 14 and 15, Bowering et al. 1990) and found the new estimates were 1.58, 1.74 and 1.68 times higher in 1981, 1982, and 1984 respectively. Applying these factors directly to the consumption estimates yields revised annual estimates of 166,000 t, 268,000 t, and 349,000 t in 1981, 1982, and 1984 respectively. The average of these estimates is 261,000 t of capelin consumed.

Annual trawl estimates of abundance (ages 4-10) of Greenland halibut show year-to-year variation but the general trend is an increase to a peak during 1990 and 1991, then a sharp decline to historically low values during 1994-96 (Fig. 2). If we assume that consumption of capelin is directly proportional to Greenland halibut abundance, then consumption during 1990 would have peaked at about 395,000 tons when compared to the average of 1981, 1982, 1984 Campellen estimates for ages 4-10. This is calculated by:

$$\frac{\text{Average of 1981, 1982 and 1984 Campbellen estimates, ages 4-10}}{\text{1990 Campelen estimates, ages 4-10}} \times \text{Average consumption estimates 1981, 1982, 1984}$$

$$= \frac{\frac{(200951 + 281532 + 328035)}{3}}{409065} \times 261{,}000 = 395{,}000$$

However, Greenland halibut abundance, ages 4-10, declined after 1990. Thus, a similar calculation using the 1996 Campelen estimate (177964 individuals) would yield a consumption estimate of 172,000 t of capelin. This indicates that the decline in consumption of capelin between the early 1980's and 1996 was on the order of 89,000 t (261,000-172,000).

Although these calculations must be viewed as being very approximate considering the assumptions and approximations, they suggest that consumption of capelin by Greenland halibut has been substantial, perhaps at about 400,000 tons during 1989 and 1990. In contrast, this consumption probably dropped dramatically in the 1990's, possibly by about half, due to the decline in abundance of the ages 4-10 Greenland halibut, which prey on capelin. Overall, capelin consumption by Greenland halibut probably has declined between the early 1980's and 1996, by just under 100,000 t.

Harp Seals

In recent years, harp seals and their prey consumption have been under intense scrutiny. The most recent estimates of consumption show that 696,242 tons of capelin were consumed by harp seals in Div. 2J3KL during 1998, using average diets (G. Stenson, pers. comm.). These estimates have been made back to 1972 and are plotted with harp seal population estimates in Figure 3. It is clear that capelin consumption is closely linked to harp seal population size. The harp seal population trajectory, calculated in 1999 (G. Stenson, pers. comm.) goes back to 1972 but a comparison with an earlier estimate (Shelton et al. 1996) shows the two vectors are very close (Fig. 4). The

1996 estimates go back to the mid 1950's so it is reasonable to assume that the most recent estimates, if carried back, would follow the same pattern. Assuming capelin consumption has been directly related to harp seal abundance, this consumption was probably lowest in the late 1960's and early 1970's and highest during the most recent years.

It is interesting to compare consumption estimates from the most recent calculations with those calculated by Winters and Carscadden (1978). During the late 1970's, Winters and Carscadden (1978) noted that the population of harp seals was 1.3 million animals, which was about the same abundance used by Sergeant (1973) to calculate capelin consumption. Although Sergeant's calculations were crude, he estimated that about 400,000 tons of capelin were consumed in Canadian waters and roughly 300,000 tons in eastern Newfoundland and Labrador. Since populations of harp seals in the late 1970's were similar in abundance to those used in Sergeant's calculations, Winters and Carscadden (1978) used the estimate of 300,000 tons as a consumption estimate for that time period. However, the most recent estimates of harp seals (1999 estimates, G. Stenson, pers. comm.) show that 1975, 1976, 1977, and 1978 estimates as 2.12, 2.16, 2.22, and 2.30 million seals respectively. Thus, using the revised population estimates, the estimated consumption might have been calculated as

$$\frac{2.2\ \text{(1975-78 average seal abundance)} \times 300{,}000}{1.3\ \text{(capelin seal abundance estimate)}} = 508{,}000 \text{ tons}$$

However, the actual consumption for that 1975-78 period, based on the most recent calculations is 296,277 tons. Thus, although the harp seal population estimates for the mid to late 1970's are now higher, the capelin consumption estimates are similar to those presented by Winters and Carscadden (1978).

If we compare the years 1978 and 1998, the harp seal population has grown from 2.3 to 5.2 millions animals or an increase of 2.26 times. During that same time, capelin consumption has increased from 311,957 tons to 696,242 tons or a factor of 2.23.

If we compare the same time periods as we have for the other predators, i.e. early 1980's to the mid 1990's, we find capelin consumption has increased by about 333,220 tons (696,242-363,022 = 1998 consumption - 1982 consumption).

Other Predators

In the preceding sections, I have concentrated on predators that tend to consume large quantities of capelin and for which there are consumption estimates over a number of years. There are, however, consumption estimates for a few other predators and these are provided below.

Seabirds

There are several species of seabirds that consume capelin (Brown and Nettleship 1984) but few capelin consumption estimates for the Div. 2J3KL area are available. Most seabirds studies have been conducted during the breeding time which generally overlaps the inshore spawning migration of capelin. Although capelin is clearly a key component of the chick and adult diet at this time, there are large gaps in our knowledge of seabird distribution and feeding at other times of the year. Brown and Nettleship (1984) estimated that about 7300 t of capelin were consumed by herring gulls, black-legged kittewakes, common murres and Atlantic puffin between the 45 day period of 1 July-15 August. Their estimate of 3891 t of capelin by Atlantic puffins is comparable to a 5102 t estimate made by Rodway and Montevecchi (1996). Brown and Nettleship (1984) extrapolated their calculations to all seabirds throughout the year and concluded that the annual consumption of capelin by seabirds was on the order of 250,000 t.

Hooded Seals

Hammill and Stenson (1997) provided consumption estimates for four seal species, including hooded seals. For Div. 2J3KL they had feeding data for hooded seals from both inshore and offshore areas. The estimates of capelin consumption were lower than many other predators, ranging from a low of 2255 tons in 1990 to a high of 2994 tons in 1996 (the years of the study). Since the estimates of consumption are directly proportional to predator abundance, the increase between 1990 and 1996 reflects an increase in hooded seal abundance.

The authors also included consumption estimates for hooded seals in the Flemish Cap area. There were no feeding data from this area so Hammill and Stenson (1997) used stomach content data collected in Div. 2J3KL. As a result, there are estimates of capelin consumption in the Flemish Cap area, an area where capelin occur only rarely (Frank et al. 1996). Frank et al.

(1996) reported that capelin did occur on the Flemish Cap during the 1990's, which overlapped the time period examined by Hammill and Stenson (1997). It is therefore conceivable that hooded seals could have consumed capelin in that area during the 1990's but the estimates provided are equally likely to be artifacts of the methodology.

Baleen Whales

Winters and Carscadden (1978) estimated that capelin consumption in the mid 1970's by fin and minke whales was about 250,000 and 35,000 tons respectively. Consumption of capelin by these predators at population abundances prior to the predator's decline might have been 360,000 tons for fin whales and 50,000 tons for minke whales. These whales have not been hunted since the Winters and Carscadden's (1978) estimates so it is likely that predator abundance and consumption of capelin is now higher.

Humpback whales also consume capelin in Newfoundland waters during the summer and autumn. To my knowledge, capelin consumption by humpbacks has not been estimated. Whitehead (1981) estimated that approximately 2000 humpbacks occur in Newfoundland waters each year. Piatt et al. (1989) provided local estimates (Witless Bay) of capelin consumption estimating that the maximum consumption of capelin per day was 9.5 t (1982-85) with humpbacks consuming 79%. It is not possible however to extrapolate these estimates to the entire foraging area of humpbacks.

Cetaceans are also important consumers in Icelandic waters. Sigurjonsson and Vikingsson (1998) estimated that humpback whales near Iceland and north of 60°N consumed 236,000-290,000 t of fish annually, based on two methods of calculation. They did not provide an estimate for capelin only. They assumed 120 days of feeding per year and used feeding data from Canadian waters (Mitchell 1973). Their abundance estimate of 1796 whales came from sightings surveys.

Given that the abundance estimates for humpbacks in the Newfoundland area and Iceland area are similar, we could assume that the annual fish consumption of about 250,000 tons is also similar, however, the total consumption of capelin cannot be derived.

American plaice

Although capelin contribute to the diets of American plaice (Pitt 1973), there are no capelin consumption estimates available. American plaice stocks in Div. 3LNO have experienced dramatic declines. For example, based on research trawl data, the female spawning stock biomass in 1995 was 95% less than estimates from the mid 1980's (p. 86, Anon. 1998b). Assuming that overall capelin consumption is proportional to predator abundance, capelin consumption by American plaice has undoubtedly declined.

Salmon

The situation with salmon is similar to that of American plaice. Salmon consume capelin (Lear 1972) but no consumption estimates have been made. Salmon abundance is at a historical low (Anon. 1999) implying that capelin consumption is also very low.

Discussion

The North Atlantic ecosystem is a dynamic system and as such, predator-prey interactions are probably constantly changing. Recent extreme changes in some major predator populations (e.g. decline in northern cod and increase in harp seals) have probably resulted in dramatic changes in capelin consumption as well. As previously noted, the estimates of capelin consumption are very approximate and should be treated with caution. Furthermore, such simple single predator-single prey calculations do not account for more complex interactions that might be occurring between the major prey and predator species. Thus, all conclusions from the comparisons in this paper should be made with these caveats in mind.

A brief summary of likely population trends of major capelin predators and estimates of change in annual capelin production between the early 1980's and the present is given in Table 2. It is clear that for many species, there are no data available but taken together, they may account for significant annual capelin consumption. Of the three predator species for which historical capelin consumption estimates are available, two species, namely cod and Greenland halibut, have declined. Harp seals have increased in abundance. For Greenland halibut, the decline in consumption between the early 1980's and present has been in the order of 100,000 tons. For cod, the decline in consumption is much larger, in the order of 1,000,000 tons. For seals, the increase in capelin consumption over the same period is just over 300,000 tons. Thus, even with the uncertainties associated with this type of exercise and comparison, it is probable that the increase in consumption of capelin by seals has not been as great as the decrease in consumption by groundfish predators.

References

Anonymous. 1994. Capelin in SA2 + Div. 3KL. Compiled by J. Carscadden. DFO Atl. Fish. Res. Doc. 94/18, 164 p.

1995. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 95/70, 338 p.

1996. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 96/90, 269 p.

1997. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 97/29, 188 p.

1998a. Capelin in SA2 + Div. 3KL. CSAS Res. Doc. 98/63, 152 p.

1998b. NAFO Sci. Coun. Repts.

1999. Report of the Working Group on North Atlantic Salmon. ICES CM1999/ACFM: 14.

Bowering, W. R. 1983. Age, growth, and sexual maturity of Greenland halibut, Reinhardtius hippoglossoides (Wallbaum), in the Canadian Northwest Atlantic. Fish. Bull. 81: 599-611.

Bowering, W. R., and G. R. Lilly. 1992. Greenland halibut (Reinhardtius hippoglossoides) off southern Labrador and northeastern Newfoundland (Northwest Atlantic) feed primarily on capelin (Mallotus villosus). Neth. J. of Sea. Res. 29: 211-222.

Bowering, W. R., W. B. Brodie, and J. W. Baird. 1990. An assessment of the Greenland halibut stock component in NAFO Subarea 2 and Divisions 3K and 3L. NAFO SCR Doc. 90/51, Ser. No. N1772, 21 p.

Brodie, W. B., W. R. Bowering, D. Power, and D. Orr. 1997. An assessment of Greenland halibut in NAFO Subarea 2 and Divisions 3KLMNO. NAFO SCR Doc. 97/52, Ser. No. N2886, 37 p.

Brown, R.G.B., and D. N. Nettleship. 1984. Capelin and seabirds in the northwest Atlantic. p. 184-194 In: Spec. Pub. Can. Wildlife Serv., Proceedings of the Pacific Seabird Group Symposium, Seattle, Wash., 6-8 Jan. 1982.

Campbell, J. S., and G. H. Winters. 1973. Some biological characteristics of capelin, Mallotus villosus, in the Newfoundland area. ICNAF Res. Doc. 73/90, Ser. No. 3048, 8 p.

Carscadden, J. E. 1984. Capelin in the northwest Atlantic. p. 170-183. In: Spec. Pub. Can. Wildlife Serv., Proceedings of the Pacific Seabird Group Symposium, Seattle, Wash., 6-8 Jan. 1982.

Carscadden, J. E., B. S. Nakashima, and K. T. Frank. 1997. Effects of fish length and temperature on the timing of peak spawning in capelin (Mallotus villosus). Can. J. Fish. Aquat. Sci. 54: 781-787.

Frank, K. T., J. E. Carscadden, and J. E. Simon. 1996. Recent excursions of capelin (Mallotus villosus) to the Scotian Shelf and Flemish Cap during anomalous hydrographic conditions. Can. J. Fish. Aquat. Sci. 53: 1473-1486.

Hammill, M. O., and G. B. Stenson. 1997. Estimated prey consumption by harp seals (Phoca groenlandica), grey seals (Halichoerus gryphus), harbour seals (Phoca vitulina) and hooded seals (Cystophora cristata) in the Northwest Atlantic. NAFO SCR Doc. 97/40, Ser. No. N2872, 37 p.

Lear, W. H. 1969. The biology and fishery of the Greenland halibut (Reinhardtius hippoglossoides) in the Newfoundland area. M.Sc. Thesis, Memorial Univ. Nfld.

Lear, W. H. 1972. Food and feeding of Atlantic salmon in coastal areas and over oceanic depths. Int. Comm. Northwest Atl. Fish. Res. Bull. No. 9: 27-39.

Lilly, G. R., R. Wells, and J. Carscadden. 1981. Estimates of the possible consumption of capelin by the cod stocks in Divisions 2J3KL and 3NO. NAFO SCR Doc. 81/8, Ser. No. N272, 9 p.

Minet, J. P., and J. B. Perodou. 1978. Predation of cod, Gadus morhua, on capelin, Mallotus villosus, off eastern Newfoundland and in the Gulf of St. Lawrence. Int. Comm. Northwest Atl. Fish. Res. Bull. 13: 11-20.

Mitchell, E. 1975. Trophic relationships and competition for food in Northwest Atlantic whales. Proc. Can. Soc. Zool. Ann. Meet.: 123-133 (citation not traceable through NWAFC Library).

Nakashima, B. S. 1996. The relationship between oceanographic conditions in the 1990's and changes in spawning behaviour, growth and early life history of capelin (Mallotus villosus). NAFO Sci. Coun. Stud. 24: 55-68.

Piatt, J. F., D. A. Methven, A. E. Burger, R. L. McLagan, V. Mercer, and E. Creelman. 1989. Baleen whales and their prey in a coastal environment. Can. J. Zool. 67: 1523-1530.

Pitt, T. K. 1973. Food of American plaice (Hippoglossoides platessoides) from the Grand Bank, Newfoundland. J. Fish. Res. Board Can. 15: 295-311.

Rodway, M. S., and W. A. Montevecchi. 1996. Sampling methods for assessing the diets of Atlantic puffin chicks. Mar. Ecol. Prog. Ser. 1444: 41-55.

Sergeant, D. F. 1973. Feeding, growth and productivity of Northwest Atlantic seals. J. Fish. Res. Bd. Canada 30: 17-29.

Shelton, P. A., G. B. Stenson, B. Sjare, and W. G. Warren. 1996. Model estimates of harp seal numbers-at-age for the northwest Atlantic. NAFO Sci. Coun. Studies 26: 1-14.

Sigurjonsson, J., and G. A. Vikingsson. 1998. Seasonal abundance of and estimated food consumption by cetaceans in Icelandic and adjacent waters. J. Northw. Atl. Fish. Sci. 22: 271-287.

Turuk, T. N. 1978. The feeding of Labrador and Newfoundland cod on capelin. Trudy PINRO 41: 67-73. (Can. Transl. Fish. Aquat. Sci. 4580, 1979)

Warren, W. G. 1996. Report on the comparative fishing trial betwween the GADUS ATLANTICA and TELEOST. NAFO SCR Doc. 96/28, Ser. No. N2701, 16 p.

Whitehead, H. P. 1981. The behaviour and ecology of the humpback whale in the Northwest Atlantic. Ph.D. Thesis, Cambridge University, Cambridge.

Winters, G. H., and J. E. Carscadden. 1978. Review of capelin ecology and estimation of surplus yield from predator dynamics. Int. Comm. Northwest Atl. Fish. Res. Bull. 13: 21-30.

Table 1. Estimates of capelin consumption by cod (age 2+) using different factors.

Year	2+ cod biomass	Factor			
		0.76		1.0	
		1.27	2.38		
1962	2,722,099	2,068,795	2,722,099	3,457,066	6,4778,596
1981	957,399	727,623	957,399	1,215,897	2,278,610
1997	7,324	5,566	7,324	9,301	17,431

Table 2. Capelin predators discussed in the text, change in population abundance of the predators from the early 1980's and mid 1990's, and estimates of increase (+) or decrease (-) of capelin consumption during the same time period.

Predator	Change in Population Abundace	Increase (+) or Decrease (-) in Capelin Consumption (t)
Cod	Decrease	-1,000,000
Greenland halibut	Decrease	-89,000
Harp seals	Increase	+330,000
Seabirds	??	??
Hooded seals	Likely increase	Not significant - see text
Whales	Likely increase	??
American plaice	Decrease	Decrease
Salmon	Decrease	Decrease

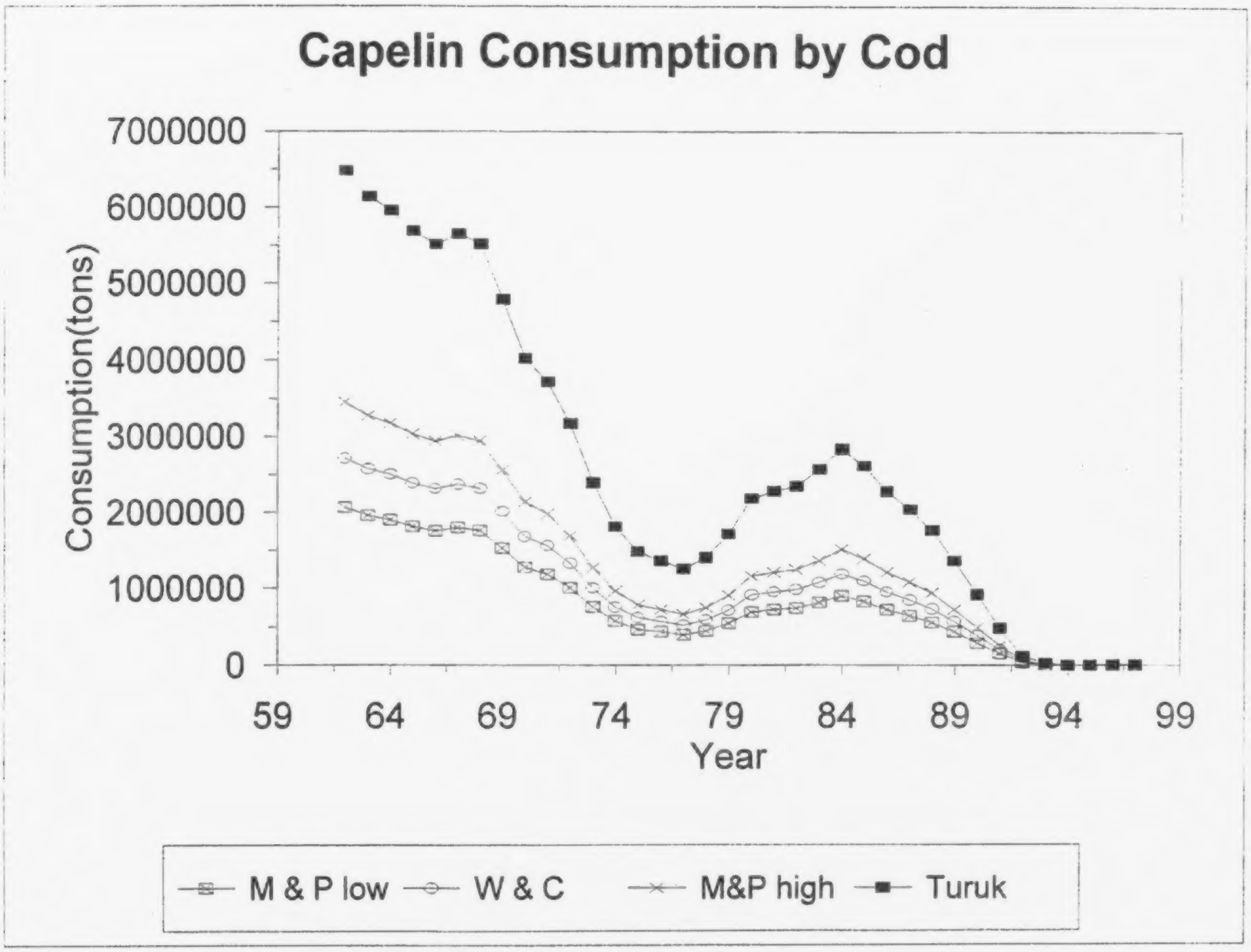

Fig. 1. Estimates of annual consumption by cod using different assumptions regarding biomass of capelin consumed per unit weight of cod. M + Plow is Minet and Perodou, low estimate; W + C is Winters and Carscadden; M + P high is Minet and Perodou, high estimate. See text for details.

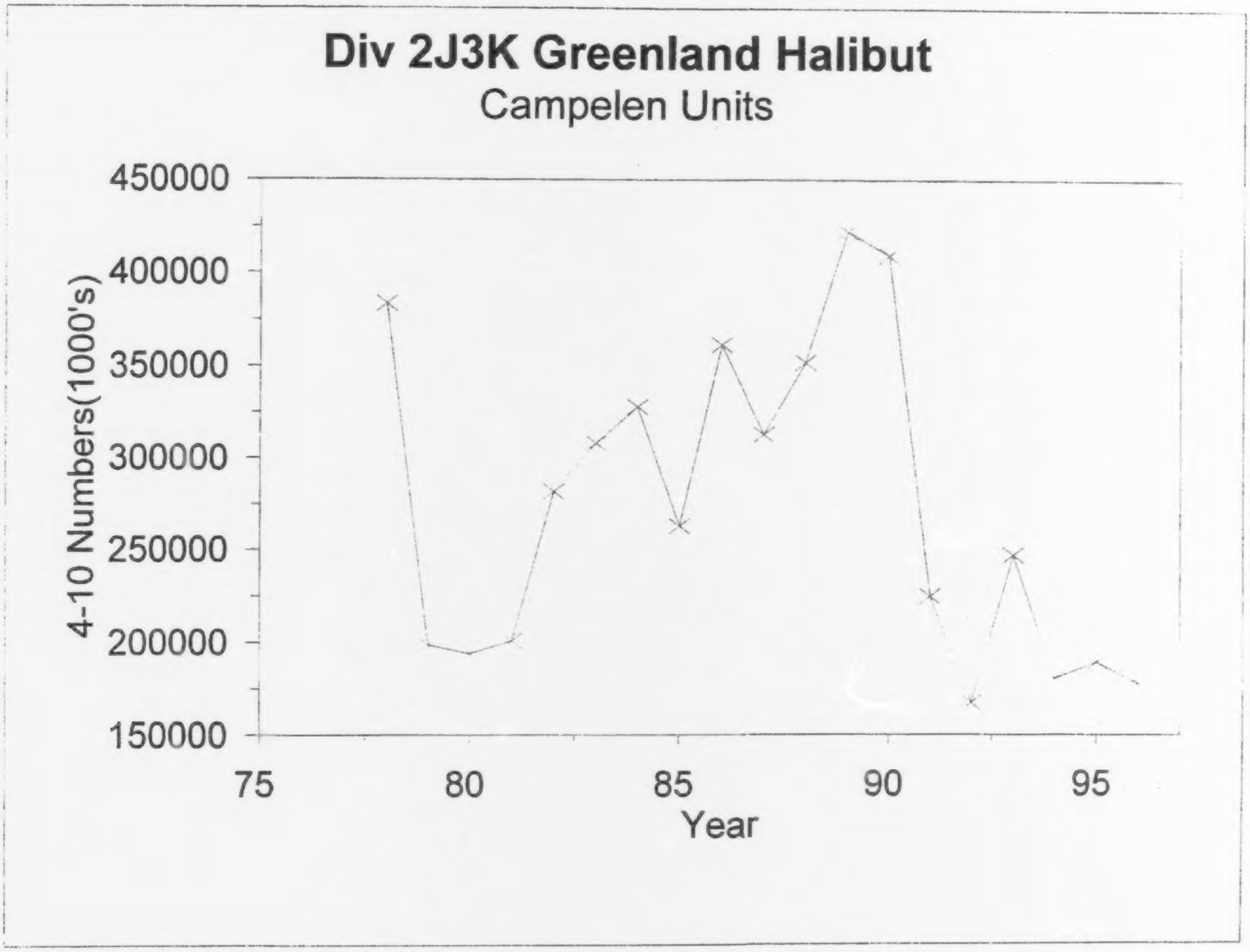

Fig. 2. Estimates of Greenland halibut numbers, ages 4-10, converted to Campelen equivalents.

2

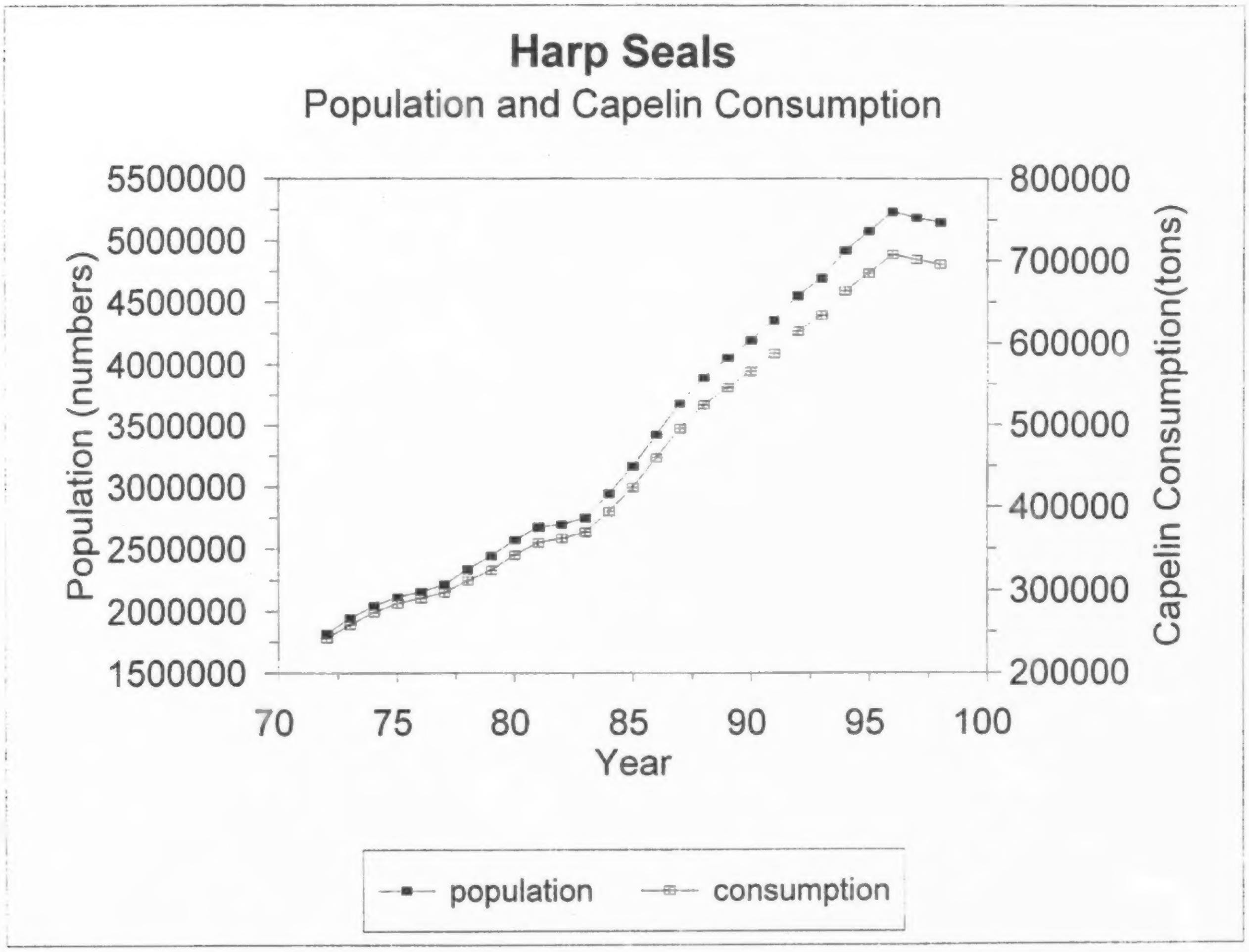

Fig. 3. Population numbers of harp seals and estimates of annual consumption of capelin by harp seals.

3

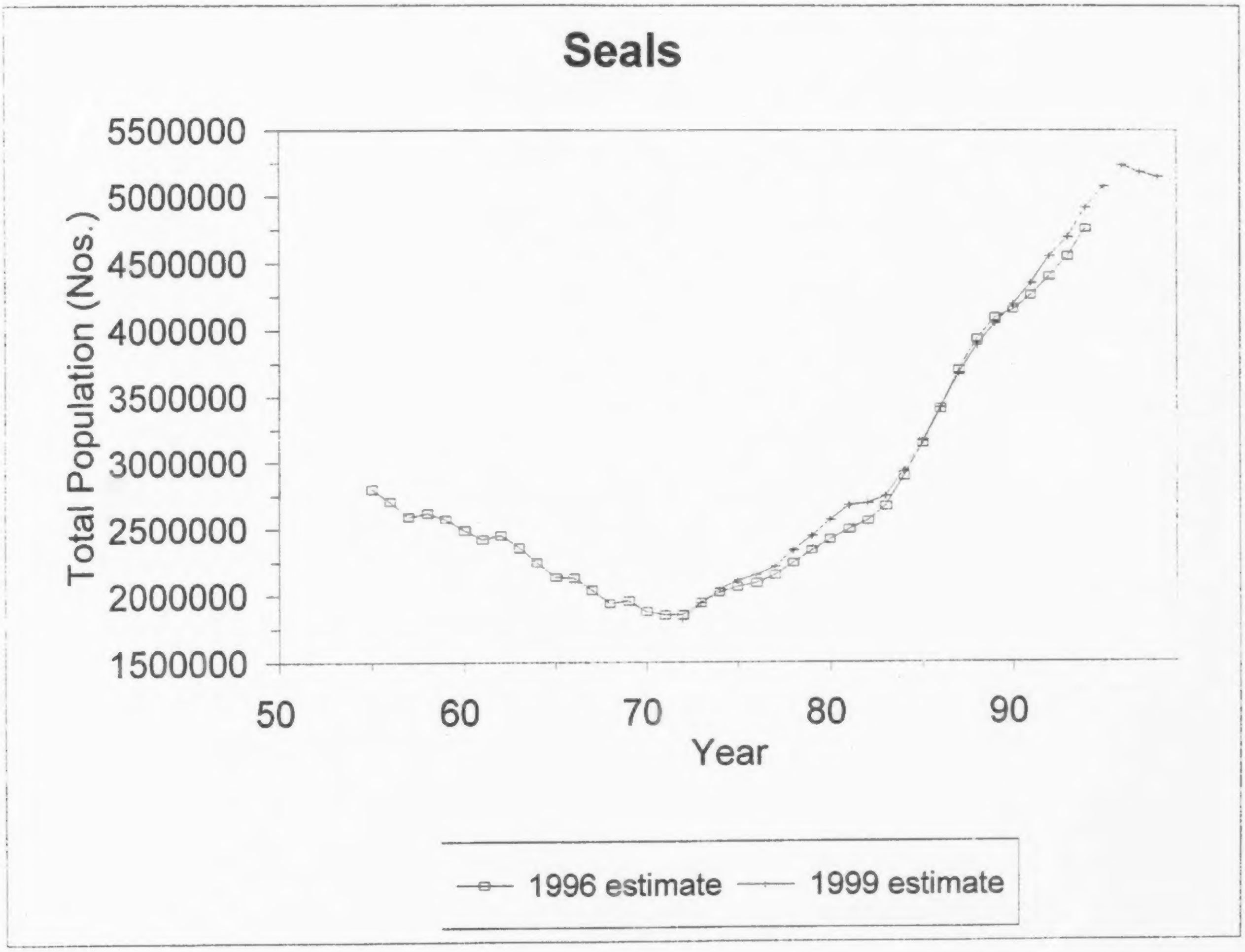

Fig. 4. Two trajectories of harp seal estimates. See text for discussion.

Predicting Mean Lengths of Female Capelin In SA 2 + Div. 3KL

by

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Introduction

In past assessments, the positive relationship between mean lengths of maturing capelin from fall offshore surveys and the mean lengths of spawning capelin the following year have been used as a basis to predict the mean lengths of mature capelin during the assessment year (Carscadden 1995, 1996, 1997). During the 1997 assessment, the prediction for 1997 using data from the fall of 1996 proved optimistic (Carscadden and Evans 1998). A closer examination of the entire series of data indicated that two relationships might exist, one for the fall-summer mean length combination 1981/82 to 1989/90, and one from 1990/91 onward. In some cases, mean lengths in the fall in the 1990's period were smaller than the 1980's but in addition, the final mature mean lengths were smaller, indicating less growth during the latter period (see Fig. 1). Carscadden and Evans (1998) noted that growth between the fall of one year and spring of the following gear could not be predicted. As a result, they provided two probability distributions using data from the 1980's and 1990's to provide insight in the likely mean lengths of females in the mature population in 1998, using the mean length observed in the fall of 1997. In this paper, we present the mean lengths of female capelin sampled in the 1998 fishery. In addition, we present another probability distribution analysis (Carscadden and Evans 1998) using historical mean length data and the observed mean lengths of female capelin during the fall of 1998.

The 1998 Analysis and Prediction

From capelin bycatch in the Campelen gear in the autumn 1997 groundfish survey in Div. 2J3KL, the mean length of maturing females was 144 mm. Using data from the 1980's and 1990's, probability distributions were presented. If growth increments (between fall 1997 and spring 1998) resembled those observed in the 1990's, there was about a 60% probability that the mean length would be greater than about 151 mm. This mean length corresponds to approximately 50 count, thus, there would be about 60% chance that the average count would be 50 or less. On the other hand, if growth during the same time period was more typical of the 1980's, there was a 100% probability that the mean lengths would be greater than about 151 mm and counts 50 or less (Carscadden and Evans 1998).

The mean length of mature female capelin in the 1998 commercial fishery was 147 mm (Fig. 1). This point falls in the 1990's group, indicating that growth between the fall of 1997 and spawning season of 1998 was again low. The fishing industry reported that fish were smaller in Div. 3L than in Div. 3K. Our data support this report. The mean length of female capelin in Div. 3L was 0.5 mm smaller than in Div. 3K (Fig. 2).

Predicted Mean Length of Females in 1999

The only source of samples from the fall in 1998 is the bycatch in the Div. 2J3KL groundfish survey using Campelen gear. Sampling procedure in 1998 was the same as 1997, that is, lengths were recorded from all individuals in catches less than 200 fish. For larger catches, a random sample of 200 fish was collected and lengths recorded from this sample. The overall mean length of maturing female capelin in the fall of 1998 was 139 mm, one of the smallest estimates in the series (Table 1).

Using the non-parametric methods of Evans and Rice (1988) we present a probability distribution for the mean length in 1999, based on the mean length of 139 mm measured in the fall of 1998. Two distributions are present: one if the increments of the 1990's prevail, another (higher) if the system reverts to the increments of the 1980's. For reference we also illustrate the positions of lengths corresponding to the approximate 50 and 40 counts (Fig. 3). The positions of the 50 and 40 counts are approximate. They are derived from length-weight regressions for females during the spawning season and the weights of these females (from which counts are derived) are variable at this time because of rapid maturation. However, they do offer guidance in evaluating the probable sizes of females in 1999. If growth is similar to that observed in the 1990's, there is virtually no chance that the average count will be less than 50 in 1999. If growth is similar to that of the 1980's, there is a 75% chance that the average counts will be less than 50.

These graphs (Fig. 3) describe only the variation in increments observed since 1981 and cannot rule out accidents as yet unobserved. The analysis is based on pooled data from the stock area and consequently, it is not possible to account for differences that may occur between geographical areas and between spawning runs.

References

Carscadden, J. 1995. Mean lengths and age compositions of capelin, offshore and inshore. p. 193-215. In: Anon. Capelin in SA2 + Div. 3L. DFO Atl. Fish. Res. Doc. 96/70, 338 p.

1996. Expected mean lengths of mature female capelin during 1996. p. 200-208. In: Anon. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 96/90, 269 p.

1997. Predicting mean lengths of capelin. P. 148-158. In: Anon. Capelin in SA2 + Div. 3KL. DFO CSAS Res. Doc. 97/29, 188 p.

Carscadden, J., and G. T. Evans. 1998. Predicting mean lengths of female capelin in SA2 + Div. 3KL. P. 72-90. In: Anon. Capelin in SA2 + Div. 3KL. DFO CSAS Res. Doc. 98/63, 152 p.

Evans, G. T., and J. C. Rice. 1998. Predicting recruitment from stock size without the mediation of a functional relation. J. Cons. Int. Explor. Mer 44: 111-122.

Table 1. Mean lengths of mature females inshore during the spawning season and maturing females during the fall. All inshore mean lengths are derived from fishery data except 1994 and 1995 which are derived from collections from spawning beaches. The lengths are provided for the actual year of collection, however, the relationships illustrated in Figures 1 and 2 compare mean lengths in the fall to mean lengths inshore the following year.

Year	Mean lengths inshore (mm)	Mean lengths fall (mm)
1981		137
1982	166	147
1983	163	151
1984	170	146
1985	161	146
1986	165	163
1987	172	160
1988	170	148
1989	167	150
1990	167	159
1991	159	145
1992	151	146
1993	152	143
1994	152	131
1995	142	141
1996	151	149
1997	149	144
1998	147	139

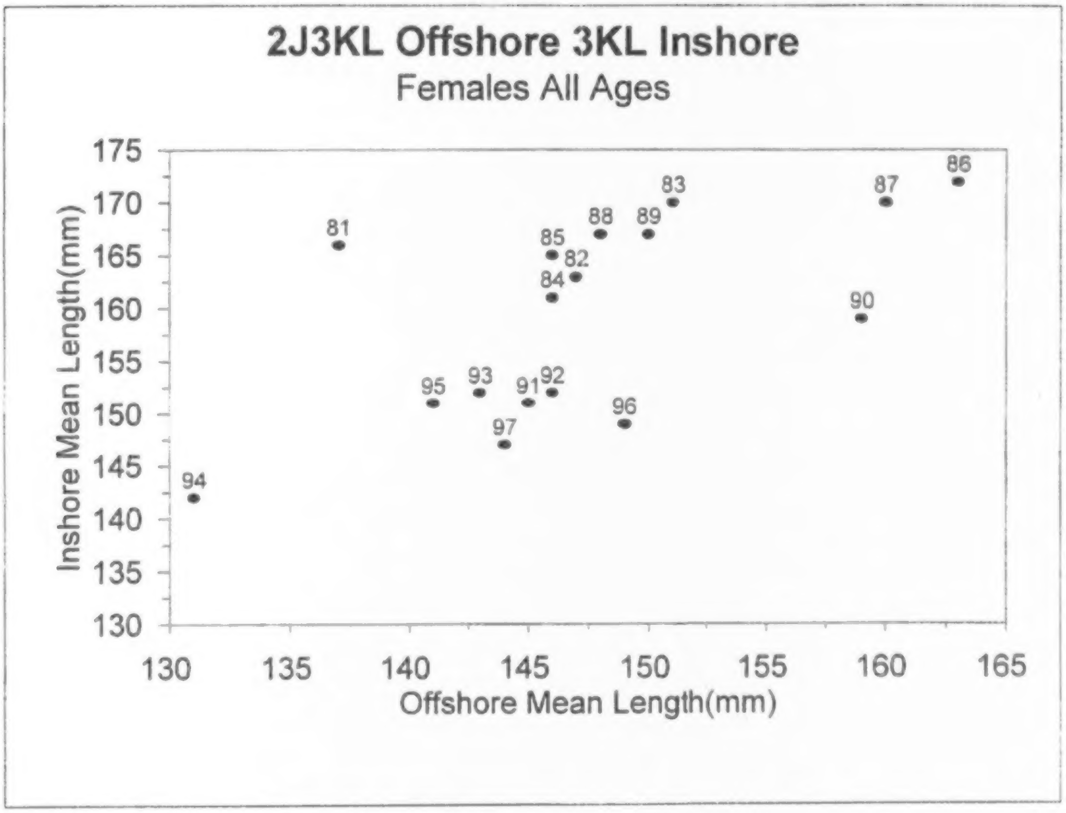

Fig. 1. Relationship between mean lengths of mature female capelin from fall offshore surveys and from inshore the following year, fall 1981 to inshore 1998. The labels (year) are the year the fall samples were collected (eg. 81 point is for fall 1981/inshore 1982).

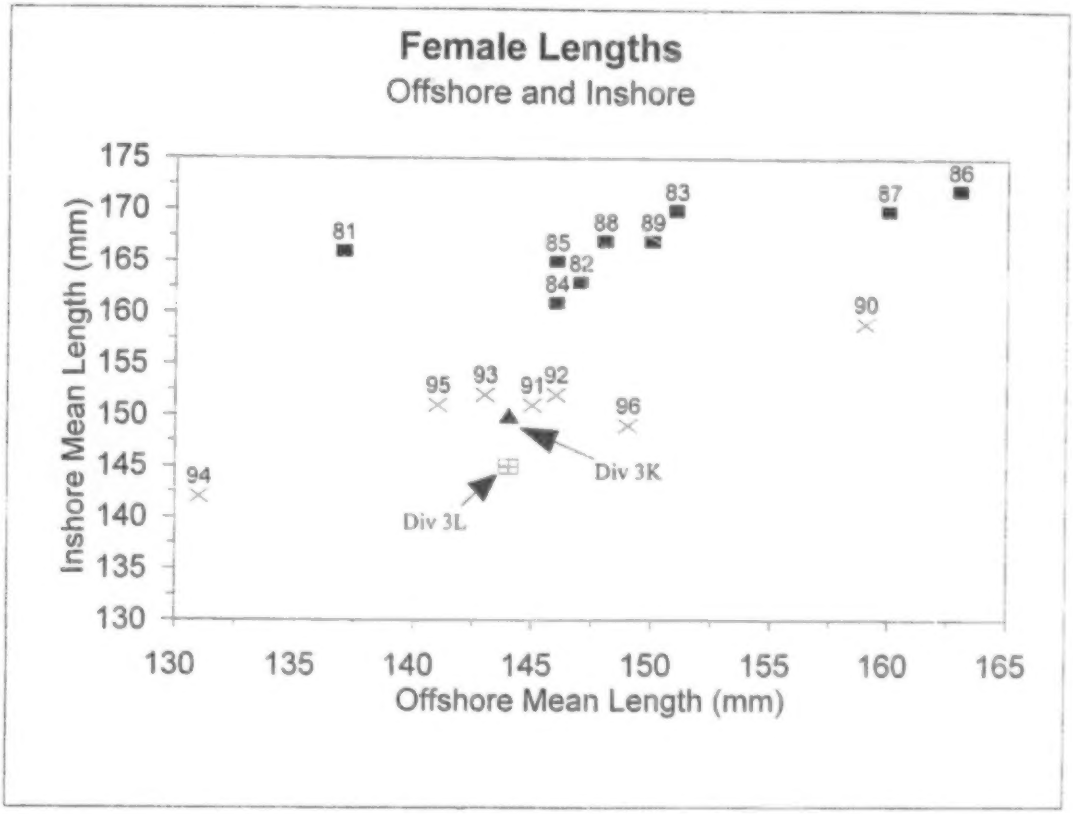

Fig. 2. The same data as in Figure 1 except the 1998 inshore samples have been split geographically to illustrate the differences in mean lengths between females from Div. 3L and Div. 3K.

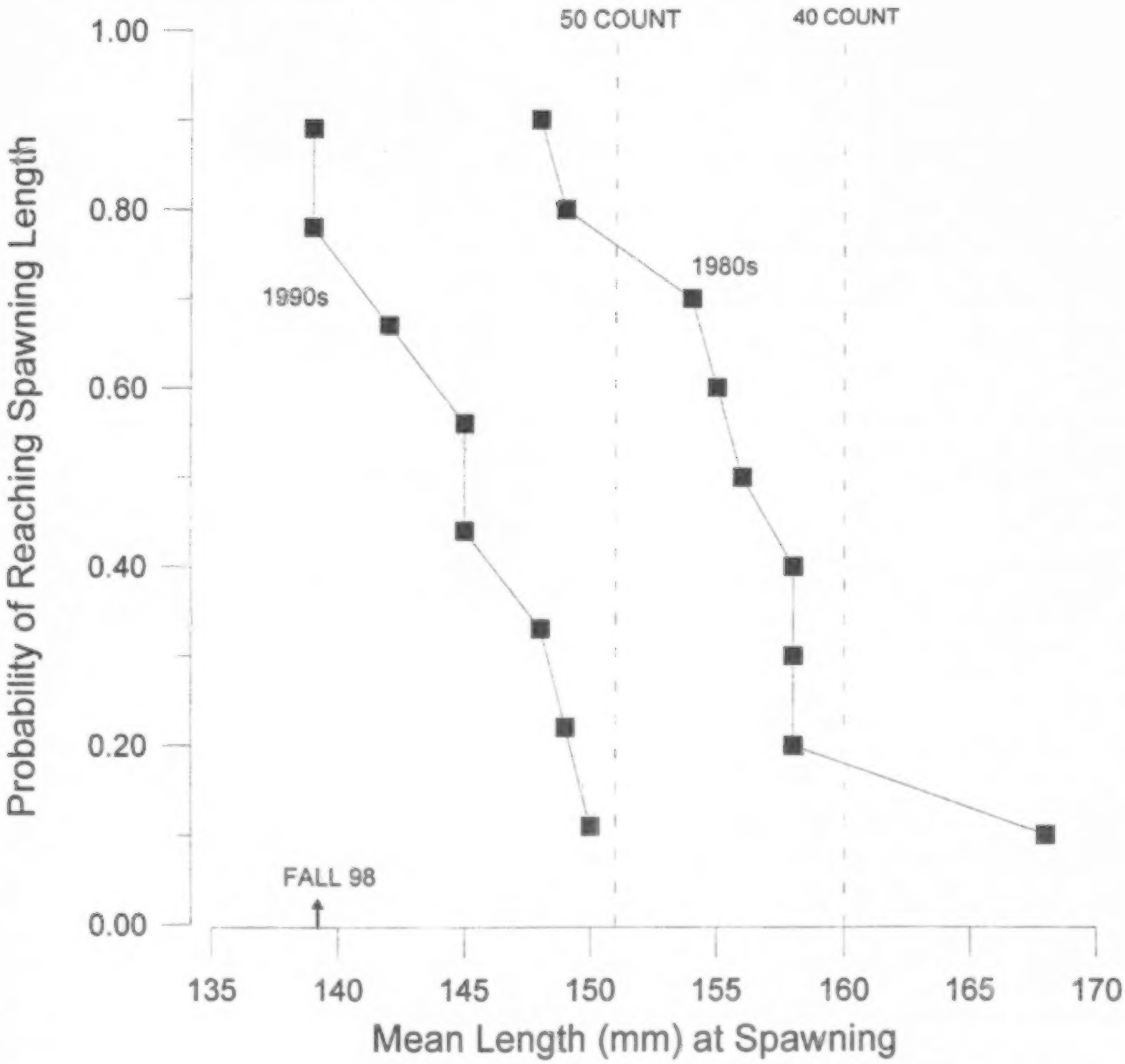

Fig. 3. Probabilities of reaching particular spawning lengths using growth increments observed during the 1980's and 1990's, and a fall mean length of 139 mm. The dotted lines identify the approximate mean lengths corresponding to 50 and 40 count (numbers of females per kg) capelin.

Chapter 10

Yearclass Strength of Capelin (*Mallotus villosus*) Using a Weighted Multiplicative Model

by

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Introduction

The multiplicative model provides an objective framework for combining indices from a variety of sources into a single compromise index (see Myers et al. 1993). This approach is particularly attractive for extraction of the yearclass effect because multiple estimates from several abundance indices can be combined over a life-span. The multiplicative approach was applied to capelin for the first time in the 1995 assessment (Anon. 1995). Now we drop the assumption of equal weighting of the indices. For the 1999 assessment, a weighted multiplicative model was developed to provide a standardized index of cohort strength.

Methods

The multiplicative cohort model assumes that the various types of abundance indices to be integrated retain their relativity throughout the time series, i.e. each index remains proportional to population abundance (and therefore each other) so that gaps and missing values can be filled in through standardization into a combined index.

The general multiplicative model took the form:

$$N_{ijkt} = I.C_k.S_j{*}A_i.\epsilon$$

where I = intercept
C_k = cohort effect
S_j = survey effect for $j = 1 \ldots 12$
A_i = age effect for $i = 0 \ldots 5$
ϵ = residuals from fitted model

and N_{ijkt} = number at age i from survey j belonging to cohort k to what is in year t.

All variables were log-transformed (i.e. multiplicative model becomes an additive model) and the estimated cohort strengths were obtained after exponentiation.

A multiplicative analysis was performed as in Anon. (1995). The variance of each index about the combined estimate was computed. For the group of indices comprising 1/3 of the total that had the smallest variances, the variance was replaced by the largest variance in the group. Thus exceptionally, possibly accidentally small variances were ignored. The multiplicative analysis was then repeated with each index weighted by the reciprocal of its variance.

For the most recent yearclass, a probability distribution for yearclass strength was developed combining the empirical distributions for expected yearclass strength and expected catchability of the few available indices, using Bayes rule.

To develop a standardized cohort index for the 1999 assessment, a multiplicative model was applied to twelve indices. Seven of the indices were first accepted as the basis for the 1996 assessment, i.e. catch rates from purse seines and traps, the aerial survey index, egg deposition, the Russian 2J3K CPUE, and Canadian 2J3K and 3L fall bycatch indices from offshore groundfish surveys. Five indices that were the basis of a standardized recruitment index in the 1998 assessment (Nakashima 1998) were combined with the original seven indices for the 1999 assessment.

Results and Discussion

Indices

The multiplicative model was applied to the following indices as a basis for developing a cohort index for the 1999 assessment of capelin (Appendix A):

1. aerial survey index 1982-98, excluding 1991;
2. egg deposition index 1990-98;
3. purse seine catch rate index 1981-93, 1996;
4. integrated trap catch rate index 1981-93;
5. groundfish 3L fall bycatch 1985-94;
6. groundfish 2J3K fall bycatch 1985-94;
7. Russian 2J3K fall commercial catch rate index 1972-91;
8. Conception Bay sediment larval index 1987, 1989-93;
9. Bellevue Beach sediment larval index 1990-98;
10. Bellevue Beach emergent larval index 1990-96, 1998;
11. Offshore Div. 2J3KLNO 0-group index 1994-98;
12. Offshore Div. 2J3KLNO age 1 index 1994-98.

(a) Aerial survey index

The aerial survey in 1998 covered two transects (Nakashima 1999). We used a multiplicative analysis of the three transects (the transect covering the outer part of Conception Bay was last covered in 1996) as the aerial survey index. The 1998 estimate was partitioned using the age composition derived for Bellevue Beach spawners. The index assumes that the overall trend observed in the two bays is indicative of the whole stock area.

(b) Egg deposition index

Egg deposition (stages I-II, integrated for each beach) has been estimated since 1990 for several beaches on the northeast coast. Since 1996 only Bellevue Beach has been surveyed. Because it is unlikely that we will reactivate the closed sites, we decided to use only the Bellevue data series in this assessment. Past assessments (e.g. Nakashima 1998) employed a normalized series, however this assessment uses the actual estimates from the Bellevue site. To estimate the number of females we divided egg deposition by the mean female weight in gm. The estimate was then partitioned for the cohort model using the female age composition from biological samples collected at Bellevue Beach (Nakashima and Slaney 1999a). The egg deposition time series was first adopted as an index in the 1996 assessment (Winters 1996) and serves as an indirect measure of female spawner escapement. Retention of the index in the analysis assumes that observations at Bellevue Beach are indicative of the overall trend in beach spawning for Div. 3KL.

(c) Purse seine index

Data were available to estimate a purse seine catch rate (catch per fishing day) for the 1998 mobile fishery. Details concerning the purse seine fishery in 1998 are in Nakashima and Slaney (1999b). The purse seine catch rate for 1998 was not used in the standardized cohort model this year. The reduced effort and nature of the fishery created difficulties in evaluating the relevance of the current catch rate to those in the early part of the series.

(d) Integrated trap index

Data were unavailable from the research logbook survey to estimate an integrated trap index for 1998. The monitoring program to determine area openings and marketing constraints have changed fishing practices. Also catch rates for trap fishery were only available from a small portion of the stock area (Southern Shore, Notre Dame Bay, and White Bay) with most of the data coming from the White Bay area (Nakashima and Slaney 1999b). No acceptable method was available to make the 1998 estimate compatible with estimates earlier in the time series. Consequently the 1998 estimate was not used in the analysis.

(e) Offshore indices

These include the Russian 2J3K CPUE series and the 2J3K and 3L bycatch (%) of capelin in the fall 2J3KL groundfish survey (see Lilly 1995). The Russian 2J3K CPUE series ended in 1991. The two fall groundfish bycatch indices ended in 1994 when the survey fishing gear was changed from an Engels 145 high-lift trawl to a Campelen 1800 shrimp trawl.

(f) Inshore 0-group indices

The inshore indices were based on very early estimates of 0-group fish. Sediment larvae are newly hatched capelin larvae resident in beach sediments for 1-5 days. When larvae are released from beach sediments into the water column they are then termed emergent larvae. Sediment larvae were estimated from 15 Conception Bay beaches in 1987 and 1989-93 (Winters et al. 1996) and from 1-6 beaches along the northeast coast since 1990. Emergent larvae were also enumerated at northeast coast beaches from 1990-96 and in 1998. For the 1999 assessment, the Conception Bay sediment larval index was retained. However, only the data from Bellevue Beach sediment larvae and emergent larvae were used in the 1999 assessment (Nakashima and Slaney 1999a). Similar to the egg deposition index, there is no expectation that sites studied in 1991-94 would ever be sampled again.

(g) Offshore 0-group and age 1 indices

An 0-group index and an age 1 index from annual offshore surveys conducted in August-September since 1994 (Anderson and Dalley 1999) were incorporated into the multiplicative cohort model for the first time. Previously both indices were part of a recruitment index (Nakashima 1998). 0-group capelin are collected by bongos and age 1 capelin are collected using an IGYPT trawl at the same stations during the offshore 0-group survey (Anderson and Dalley 1999). In the combined recruitment index (e.g. Nakashima 1998), these two indices began in 1991, however Anderson and Dalley (1999) argued that only since 1994 have the survey coverage and sampling methodologies been relatively consistent.

Accordingly, the time series for both indices used in the 1999 assessment was 1994-98.

Model Development

Indices used in the weighted model are displayed in Figure 1. A Bayes update to better estimate the most recent yearclass (1998 in this example) is shown in Figure 2. A comparison of outcomes assuming equal weighting as in previous assessments and the weighted version suggests small differences between the two (Fig. 3). The 1998 estimate is from the model results and not the Bayes estimate.

Summary

For the 1999 assessment, the weighted model was adopted to estimate standardized cohort abundance trends. The 1996 yearclass estimates at age 2 from the both the aerial survey and the egg deposition study show this yearclass is relatively strong. Even at the lower 95% confidence interval the estimate is one of the highest in the series. However, there is considerable variation and therefore uncertainty about the estimate. As the yearclass ages and estimates at older ages become available, the relative strength of the 1996 cohort will be better estimated.

Based on the weighted multiplicative analysis, the 1996 yearclass is the strongest yearclass in the time series and is likely to dominate the 1999 spawning stock. The 1996 yearclass was relatively strong in the recruitment series (Nakashima 1998). The 1997 yearclass is weaker than the 1996 yearclass, however estimates were only available at the 0-group and age 1 stages. The 1998 yearclass will not be part of the 1999 spawning biomass, however, early indications from 0-group estimates suggest this yearclass may be as weak as the 1991 yearclass. The high variation surrounding the estimates, especially since 1993 partly reflect a continuing reduction in the number of indices available.

Besides the problems and assumptions associated with each of the indices in this analysis, there are other assumptions that have not been evaluated but may be important to interpreting the model results. Some indices do not use an independently derived age composition. For example, the egg deposition and aerial survey indices use the same age composition derived from Bellevue Beach spawners since 1996. The results of the multiplicative analysis must be considered with caution in light of these and other assumptions whose effects have not been evaluated.

References

Anon. 1995. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 95/70.

Anderson, J. T., E. L. Dalley, and D. J. Davis. Year-class strength of Northwest Atlantic capelin (2J3KLNO) estimated at the larval stage and age one based on the pelagic juvenile fish surveys, 1994-98. pp. . In: Anon. Capelin in SA2 + Div. 3KL. CSAS Res. Doc. 99/.

Lilly, G. R. 1995. Bycatches of capelin during autumn bottom trawl surveys in Divisions 2J3KLNO with emphasis on 1994. pp. 110-132. In: Anon. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 95/70.

Myers, R. A., K. F. Drinkwater, N. J. Barrowman, and J. W. Baird. 1993. Salinity and recruitment of Atlantic cod (Gadus morhua) in the Newfoundland region. Can. J. Fish. Aquat. Sci. 50: 1599-1609.

Nakashima, B. S. 1998. Relative multiplicative trends in biomass, cohort abundance, and recruitment of capelin (Mallotus villosus). pp. 134-152. In: Anon. Capelin in SA2 + Div. 3KL. CSAS Res. Doc. 98/63.

Nakashima, B. S. 1999. Results of the 1998 aerial survey of capelin (Mallotus villosus) schools. pp. . In: Anon. Capelin in SA2 + Div. 3KL. CSAS Res. Doc. 99/.

Nakashima, B. S. and B. W. Slaney. 1999a. Spawning and early development of capelin (Mallotus villosus) from Bellevue Beach, Trinity Bay in 1998. pp. . In: Anon. Capelin in SA2 + Div. 3KL. CSAS Res. Doc. 99/.

Nakashima, B. S. and B. W. Slaney. 1999b. The 1998 inshore capelin (Mallotus villosus) fishery in NAFO Div. 3KL. pp. . In: Anon. Capelin in SA2 + Div. 3KL. CSAS Res. Doc. 99/.

Winters, G. H. 1996. Further considerations of the age-structured multiplicative abundance model. pp. 81-108. In: Anon. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 96/90.

Winters, G. H., B. S. Nakashima, J. T. Anderson, and E. L. Dalley. 1996. The case for 0-group measures of capelin recruitment. pp. 109-126. In: Anon. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 96/90.

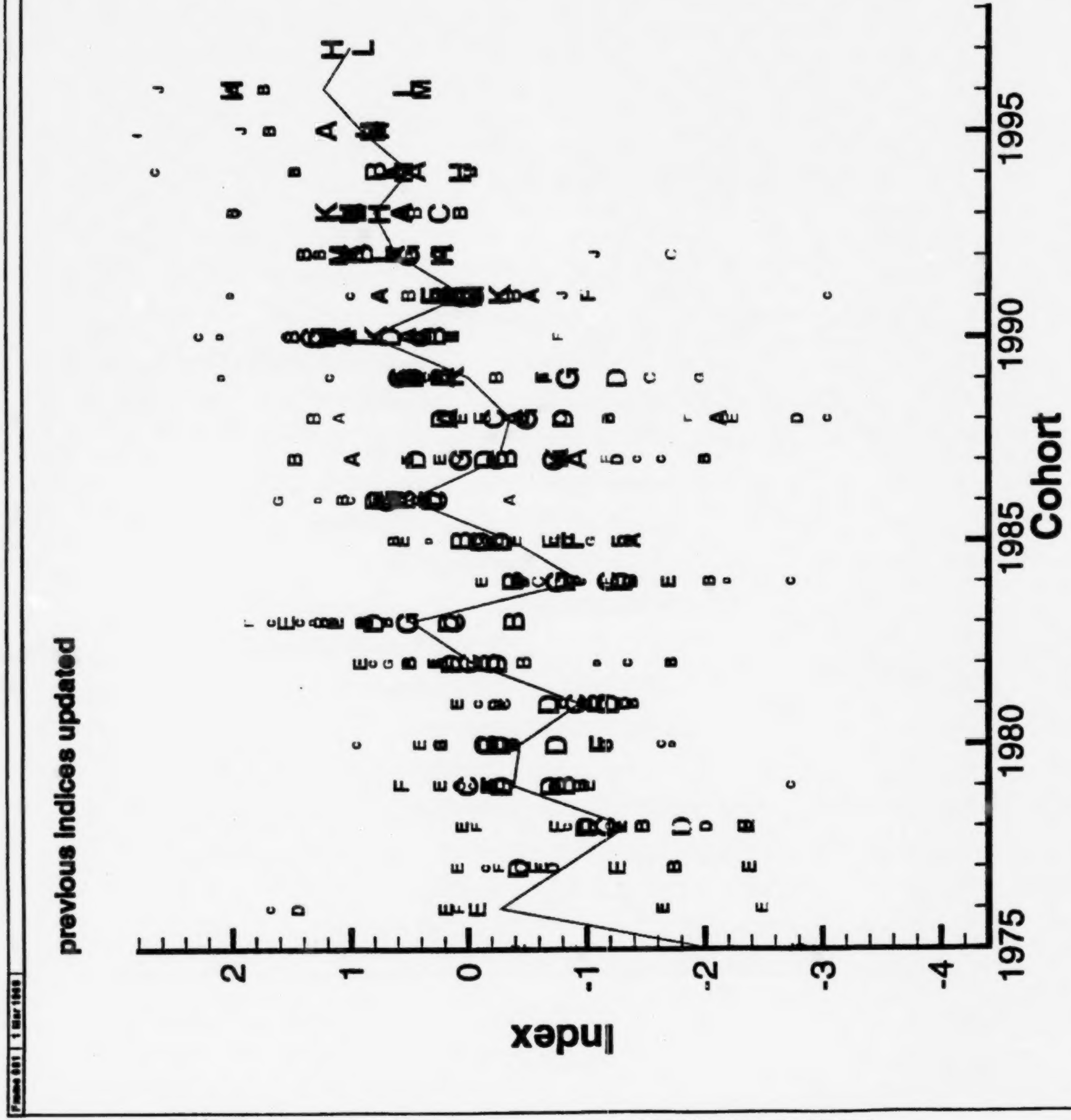

Fig. 1. The scatter of all indices used in the weighted multiplicative analysis. The letters refer to the indices in Appendix A. The larger the letter symbol the greater its contribution to the overall trend.

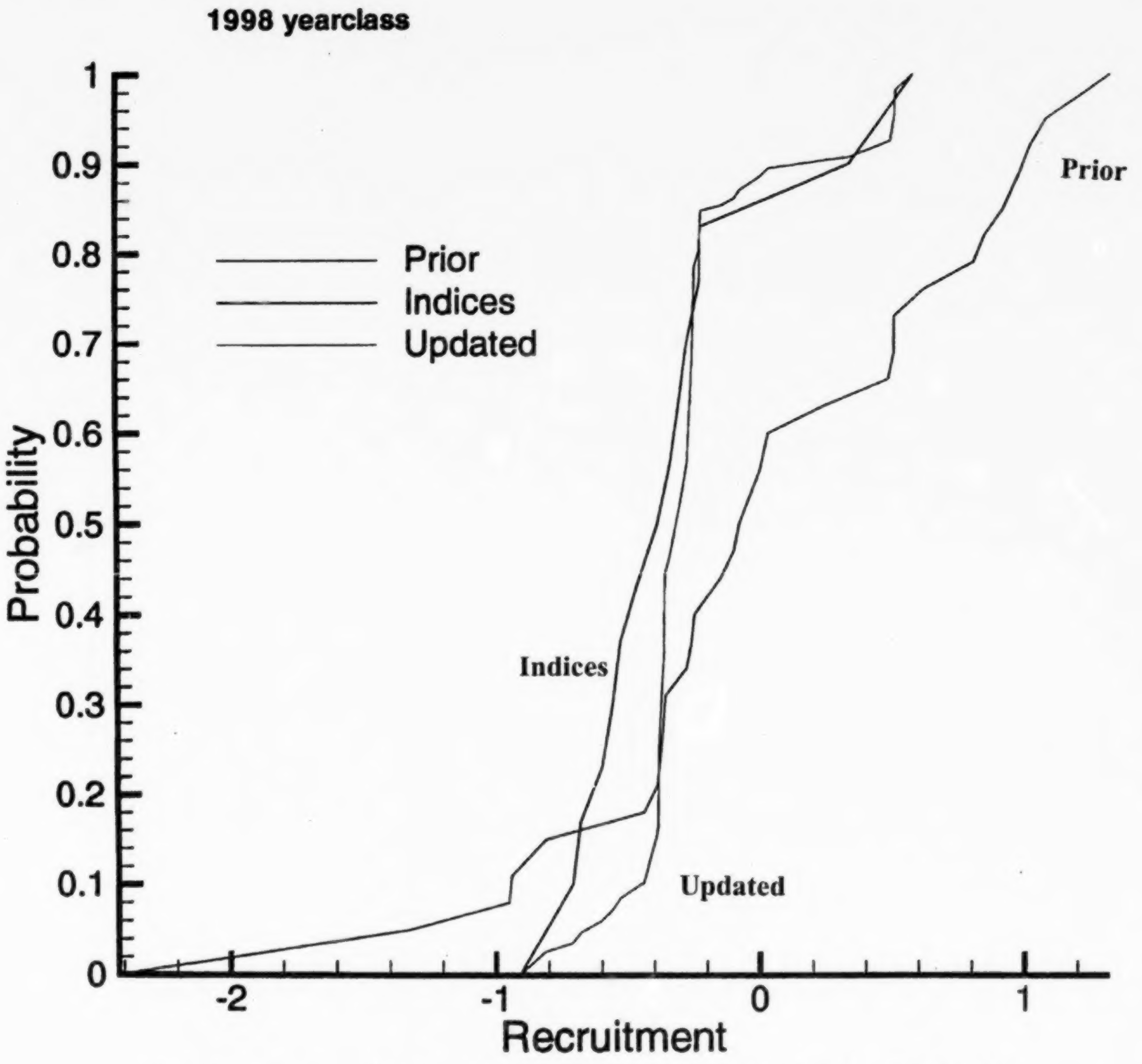

Fig. 2. Bayes update of the 1998 yearclass for the weighted multiplicative analysis.

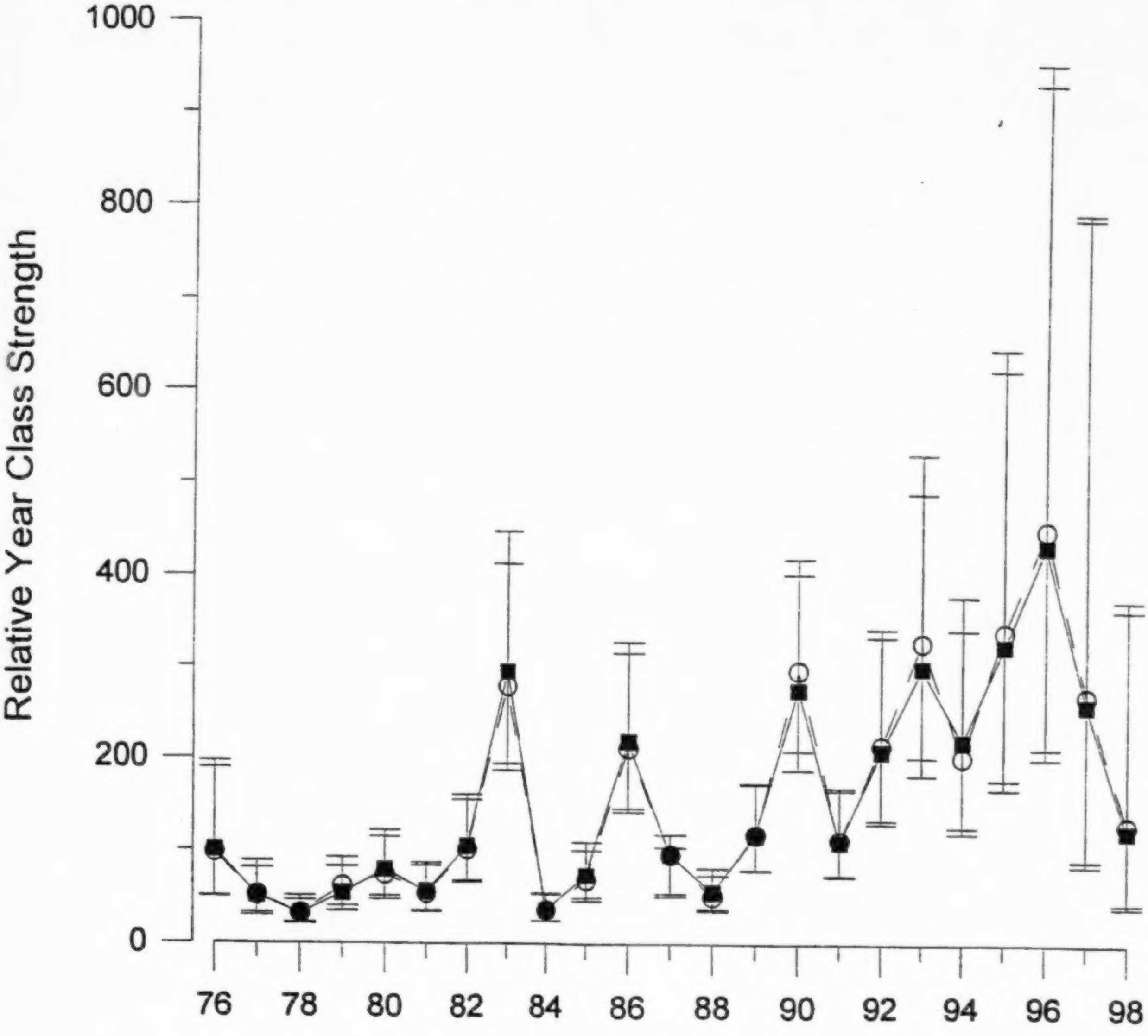

Fig. 3. A comparison of trends in standardized estimates of cohort abundance of capelin with 2 standard errors. Open circles use equal weighting and closed squares are from the weighted model.

Appendix A. Indices used in the standardized cohort abundance model.

		Age					
	Year	0	1	2	3	4	5
Egg Deposition Index (A)							
	1990	-	-	79	821	696	53
	1991	-	-	207	1620	1772	687
	1992	-	-	482	1889	2561	476
	1993	-	-	877	6609	1717	286
	1994	-	-	347	1019	520	162
	1995	-	-	1607	3955	1046	512
	1996	-	-	812	3504	1246	120
	1997	-	-	943	3213	1704	605
	1998	-	-	729	1537	395	82
Aerial Survey Index (B)							
	1982	-	-	55	939	125	36
	1983	-	-	44	1783	1095	47
	1984	-	-	32	712	885	79
	1985	-	-	354	1775	582	143
	1986	-	-	23	1438	803	56
	1987	-	-	332	1456	4521	339
	1988	-	-	515	2247	527	500
	1989	-	-	24	3637	1011	52
	1990	-	-	54	1524	1987	54
	1991	-	-	-	-	-	-
	1992	-	-	505	2660	4798	887
	1993	-	-	226	2803	1013	130
	1994	-	-	625	2678	1480	328
	1995	-	-	1297	5227	2143	913
	1996	-	-	768	5514	2074	137
	1997	-	-	944	4662	3041	820
	1998	-	-	1000	4745	1255	217
Purse Seine Catch Rate Index (C)							
	1981	-	-	1	123	124	112
	1982	-	-	3	395	58	18
	1983	-	-	14	341	210	9
	1984	-	-	4	158	248	20
	1985	-	-	64	386	143	54
	1986	-	-	1	441	215	16
	1987	-	-	14	120	643	47
	1988	-	-	42	358	107	111
	1989	-	-	3	510	163	8
	1990	-	-	10	304	413	10
	1991	-	-	50	315	219	36
	1992	-	-	150	705	89	5
	1993	-	-	42	590	42	1
	1994	-	-	-	-	-	-
	1995	-	-	-	-	-	-
	1996	-	-	217	500	35	1

Appendix A. Continued …

		Age				
	Year	0	1	2	3	4	5
Trap Catch Rate Index (integrated) (D)							
	1981	-	-	1	941	943	831
	1982	-	-	16	1908	237	95
	1983	-	-	67	1202	719	26
	1984	-	-	30	766	1095	93
	1985	-	-	334	1998	731	245
	1986	-	-	10	3013	1674	155
	1987	-	-	124	697	3216	243
	1988	-	-	323	2271	634	615
	1989	-	-	38	3447	1083	122
	1990	-	-	55	2198	3200	83
	1991	-	-	723	3180	2248	365
	1992	-	-	730	4056	648	55
	1993	-	-	665	4902	413	12
Russian 2J3K Fall Commercial Catch Rate Index (E)							
	1972	-	-	33	181	59	8
	1973	-	-	83	99	132	16
	1974	-	-	92	223	80	56
	1975	-	-	400	179	53	12
	1976	-	-	46	437	36	5
	1977	-	-	12	124	248	26
	1978	-	-	38	71	97	14
	1979	-	-	105	14	3	4
	1980	-	-	206	185	49	7
	1981	-	-	248	49	15	13
	1982	-	-	247	61	5	1
	1983	-	-	215	256	39	3
	1984	-	-	262	77	39	5
	1985	-	-	464	200	19	10
	1986	-	-	128	419	50	4
	1987	-	-	340	150	248	27
	1988	-	-	430	112	14	33
	1989	-	-	248	332	26	2
	1990	-	-	208	281	95	3
	1991	-	-	104	18	0	0

Appendix A. Continued …

		Age				
Year	0	1	2	3	4	5
Groundfish 2J3K Fall Bycatch Index (F)						
1980	-	-	34	31	7	-
1981	-	-	77	26	5	-
1982	-	-	31	97	6	-
1983	-	-	-	-	-	-
1984	-	-	-	-	-	-
1985	-	-	-	-	-	-
1986	-	-	-	-	-	-
1987	-	-	39	23	41	-
1988	-	-	131	37	2	-
1989	-	-	-	-	-	-
1990	-	-	-	-	-	-
1991	-	-	166	49	2	-
1992	-	-	248	29	1	-
1993	-	-	128	87	9	-
1994	-	-	173	20	3	-
Groundfish 3L Fall Bycatch Index (G)						
1985	-	44	220	28	-	-
1986	-	-	-	-	-	-
1987	-	-	-	-	-	-
1988	-	45	261	5	-	-
1989	-	57	140	71	-	-
1990	-	-	-	-	-	-
1991	-	352	56	12	-	-
1992	-	99	466	2	-	-
1993	-	154	125	66	-	-
Offshore 0-group Index (H)						
1994	37316	-	-	-	-	-
1995	188832	-	-	-	-	-
1996	263658	-	-	-	-	-
1997	89572	-	-	-	-	-
1998	105216	-	-	-	-	-
Offshore age I Index (J)						
1994	-	17698	-	-	-	-
1995	-	1083	-	-	-	-
1996	-	3485	-	-	-	-
1997	-	7451	-	-	-	-
1998	-	4460	-	-	-	-

Appendix A. Continued …

	Year	Age 0	1	2	3	4	5
Conception Bay Sediment Larval (K)							
	1987	61	-	-	-	-	-
	1988	-	-	-	-	-	-
	1989	147	-	-	-	-	-
	1990	285	-	-	-	-	-
	1991	99	-	-	-	-	-
	1992	340	-	-	-	-	-
	1993	432	-	-	-	-	-
Bellevue Pre-emergent Larval Index (L)							
	1990	262	-	-	-	-	-
	1991	90	-	-	-	-	-
	1992	183	-	-	-	-	-
	1993	271	-	-	-	-	-
	1994	174	-	-	-	-	-
	1995	209	-	-	-	-	-
	1996	152	-	-	-	-	-
	1997	215	-	-	-	-	-
	1998	62	-	-	-	-	-
Bellevue Emergent Larval Index (M)							
	1990	212	-	-	-	-	-
	1991	61	-	-	-	-	-
	1992	193	-	-	-	-	-
	1993	175	-	-	-	-	-
	1994	110	-	-	-	-	-
	1995	140	-	-	-	-	-
	1996	94	-	-	-	-	-
	1997	-	-	-	-	-	-
	1998	45	-	-	-	-	-

Seasonal changes in abundance, distribution, and vertical migration of capelin in Placentia Bay

by

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Abstract

The abundance and distribution of capelin (*Mallotus villosus*) in Placentia Bay, southeastern Newfoundland, were assessed during four acoustic surveys in January, March, and June 1998, and in January 1999. Most capelin observed were immature (75% < 130mm). Capelin biomass was highest in June 1998, with an acoustic estimate of 132,000t for outer Placentia Bay. Capelin biomass in the outer Bay was much lower in January 1998 (13,000t), March 1998 (2,100t), and January 1999 (390t), suggesting seasonal changes in spatial distribution. There were also seasonal differences in vertical distribution of capelin. In June capelin were close to the surface at night and near the bottom during the day. At other times no diurnal vertical migration was evident.

Introduction

No previous attempt has been made to estimate the abundance of capelin in Placentia Bay (NAFO Div. 3Ps). As part of ongoing work to monitor the distribution and abundance of cod in this area, we collected acoustic data on capelin during four surveys in 1998-99. This paper presents data on capelin biomass, distribution and vertical migration.

Acoustic surveys provide a direct method of estimating capelin abundance at sea (Toresen *et al.* 1998). Acoustic surveys for capelin off the east coast of Newfoundland and Labrador (NAFO Divisions 2J3KL) were conducted by Canada from 1981-1996 (Miller 1997), and by Russia from 1974-1993 (Bakanev & Sergeeva 1994). Biomass estimates of capelin from acoustic survey data declined dramatically in the 1990s (Carscadden & Nakashima 1997), and the reason for this decline was never fully explained. Offshore acoustic surveys were discontinued in 1996. Currently, capelin abundance is monitored offshore only through groundfish bottom-trawl by-catch (Lilly 1998), and pelagic juvenile fish surveys (Anderson & Dalley 1998). Both these methods target a relatively narrow depth range and there is potential bias due to the vertical migration behaviour of capelin (eg Shackell *et al*. 1994).

Methods

Surveys were conducted from the research vessel *Teleost* during January 6-8 1998 (Teleost 59), March 28-30 1998 (Teleost 60), June 18-25 1998 (Teleost 65), and January 13-16 1999 (Teleost 77). Acoustic data was collected using a calibrated Simrad EK500 split-beam 38-kHz echo-sounder, and analysed using custom FASIT (Fisheries Assessment and Species Identification Toolkit) software. We distinguished signals from capelin based on signal characteristics (Rose & Leggett 1988, LeFeuvre *et al*. 1999) and information from fishing sets using IGYPT mid-water and Campelen bottom trawls.

For biomass estimation, we integrated data from 11m below the surface to the bottom in 100-m horizontal bins and scaled by acoustic target strength to give estimates of areal density of capelin (fish m^{-2}) in each 100-m bin. Mean target strengths for each survey (Table 1) were calculated from fishing set length-frequency data using the relationship TS = 20logL - 73.1 where L = fish length in centimetres (Rose 1998).

The area covered varied between acoustic surveys (Fig. 1), but a region of outer Placentia Bay bounded by co-ordinates: 47°23'N, 54°29'W; 47°20'N, 54°01'W; 46°45'N, 55°31'W; 46°43'N, 54°19'W; was always surveyed with four or more transects (Fig. 1). We chose this region to compare biomass estimates between surveys. Capelin biomass was estimated from the equation:

$$B_A = w\, A \frac{\sum_{i=1}^{n_A} d_i}{n_A}$$

where B_A is the biomass of capelin in area A in kg
w is the average weight of capelin from fishing sets in kg
d_i is the areal density of capelin in the $i$th100-m bin
n_A is the number of 100-m bins in area A

Only data collected along transects were used to estimate biomass, although all data, including inter-transect bins are shown in Fig. 1. We estimated capelin biomass in the outer Bay in two ways. An estimate was calculated first for the entire region by averaging all acoustic density estimates collected along transects in the region and multiplying by the total area of the region. Second, biomass was calculated by sub-dividing the region into blocks surrounding each transect. The number and area of blocks was dependent on the number and spacing of transects (Fig. 1). Capelin biomass was then calculated independently for each transect block, and summed over the number of blocks to give an estimate of total capelin biomass in the outer Bay region (Table 2).

Surveys in January and March 1998 and in January 1999 also covered a circuit of inner Placentia Bay (Fig. 1). For these surveys we calculated an estimate of biomass in the inner Bay by averaging all acoustic density estimates north of our outer Bay region and multiplying by the total sea area of the inner Bay (Table 3). In January 1999 we observed a concentration of capelin in Paradise Sound, and calculated a separate biomass estimate for this area (Table 3). Survey coverage in the inner Bay and Paradise Sound was limited by the size of the research vessel, so biomass estimates for these areas are only general.

To examine capelin vertical distribution, we integrated acoustic signal from capelin in 5-m vertical bins (11-16m, 16-21m, 21-26m. down to the maximum depth) over a horizontal distance of 2km (~10min at survey speed of 8kts). The surface 11m was excluded because of transducer depth (6m), ship noise and near-field effects. Peak capelin depth was defined as the median depth of the vertical bin with the highest areal density of capelin. Peak capelin depth was then standardised relative to water depth according to the relationship:

$$\text{Relative capelin depth} = 1 - (\text{Peak capelin depth} / \text{Water depth})$$

Relative capelin depth provided a measure of capelin position in the water column. A value of 1 indicates capelin were at the surface. A value of 0 indicates capelin at the sea bottom. For display, we grouped acoustic data into hourly intervals and calculated the mean and standard error of relative capelin depth.

Results

Capelin biomass in outer Placentia Bay was highest in June 1998 (Table 2). Biomass in June (>130,000t) was an order of magnitude higher than the next highest estimate, from January 1998 (~12,000t). High densities of capelin were also observed offshore, south of Placentia Bay, in June 1998. Capelin biomass in the outer Bay in March 1998 (2,000-3,000t) and January 1999 (<400t) were low. Biomass estimates calculated by the two different methods (total area and transect blocks) were similar (Table 2).

Significant numbers of capelin were also observed in inner Placentia Bay, particularly in January 1999 (1,200t) and March 1998 (400t) (Table 3). In addition, a large concentration of capelin were observed in Paradise Sound in January 1999 (>1,400t), an area which we had not previously surveyed.

Capelin captured during the June survey (mean length = 125mm) were larger than those in other surveys (Fig. 2). However, the increase in capelin biomass in outer Placentia Bay from January to June was not due just to growth of individual fish. The average weight of capelin doubled over this period, from 5.03g in January to 10.34g in June, while the biomass increased by a factor of ten (Table 2). Most capelin captured in Placentia Bay were less than 130mm (Fig. 2). Larger fish only made up more than 10% of the total catch in June 1998 (Fig. 2). No information is available on capelin age or maturity from 1998 cruises, but preliminary analysis of results from January 1999 indicate that most capelin in Placentia Bay at this time were immature and ~18 months old.

A clear pattern of diurnal vertical migration was evident in acoustic data from June 1998 (Fig. 3). Capelin were close to the surface at night and near-bottom during daylight. There was little evidence of vertical movement in the other surveys. Capelin tended to be concentrated in the lower part of the water column during both day and night.

Discussion

Large numbers of capelin were observed in Placentia Bay, particularly in June. This should not be surprising, given the importance of the area as a feeding ground for seabirds, whales and cod. Most capelin in Placentia Bay were small (< 130mm), suggesting that this area is mainly used by immature fish, rather than by pre-spawning adults. Work is ongoing to examine the feeding behaviour and age-structure of capelin in the region.

The decrease in capelin biomass in the outer Bay between January and March 1998, followed by the huge increase in June indicates that there is substantial movement of capelin in this system. It appears that most capelin move out of Placentia Bay in winter, returning in the spring. There is, however, a proportion of the population which over-winters, particularly in the inner Bay. This is different from the situation described by Winters (1969) in Trinity Bay, where he observed large over-wintering concentrations in February and March which dispersed in April and May.

Capelin biomass in Placentia Bay in January 1999 (<3,100t for outer Bay, inner Bay and Paradise Sound combined) was much lower than in January 1998 (~12,000t). The research survey in 1999 was one week later than in 1998, and it is possible that most capelin had already migrated out of the Bay in 1999. Also, capelin observed in 1998 are likely to have been dominated by the 1996 year-class, which was strong (Anderson & Dalley 1998). The 1997 year-class, which seem to be the major age-class in our catches in January 1999 (O'Driscoll unpublished data), was weaker and there may have been fewer fish available in 1999.

Diurnal vertical migration has commonly been reported for capelin (Winters 1969, Kovalyvov & Kudrin 1973, Bailey *et al.* 1977, Shackell *et al.* 1994). Our results indicate that the occurrence or extent of vertical movement varies seasonally, possibly related to seasonal changes in feeding (Chan & Carscadden 1976). This has important implications for attempting to assess capelin abundance using gear which samples a fixed depth window. In January and March, capelin tended to remain close to the bottom. This may increase their vulnerability to a bottom trawl survey (Lilly 1998), while decreasing their vulnerability to a pelagic survey (Anderson & Dalley 1998). In June, we expect diurnal changes in catchability with both bottom and pelagic gears, related to the diurnal changes in the vertical distribution of capelin.

References

Anderson, J. T.and Dalley, E. L. 1998. Year-class strength of Northwest Atlantic capelin (2J3KLNO) estimated from pelagic juvenile fish surveys in the Newfoundland region 1991-97. DFO CSAS Res. Doc. 98/63: 114-133.

Bailey, R. F. J., Able, K. W. and Leggett, W. C. 1977. Seasonal and vertical distribution and growth of juvenile and adult capelin (*Mallotus villosus*) in the St. Lawrence estuary and the western Gulf of St. Lawrence. Journal of the Fisheries Research Board of Canada 34: 2030-2040.

Bakanev, V. S. and Sergeeva, T. M. 1994. Results of acoustic survey for capelin (*Mallotus villosus*) in NAFO divisions 3LNO in 1993. NAFO SCR Document 94/14 5pp.

Carscadden, J. and Nakashima, B. S. 1997. Abundance and changes in distribution, biology, and behavior of capelin in response to cooler waters of the 1990s. In Lowell Wakefield Symposium Series: Forage Fishes in Marine Ecosystems. University of Alaska Sea Grant College Program, Fairbanks, Alaska. pp 457-468.

Chan, M. and Carscadden, J. 1976. The food and feeding of capelim (*Mallotus villosus*) in the Labrador area during autumn 1973. ICNAF Res. Doc. 76/VI/20 5pp.

Kovalyov, S. M. and Kudrin, B. D. 1973. Soviet investigations on capelin in the Northwest Atlantic in 1971 and 1972. ICNAF Redbook 1973(III): 121-126.

LeFeuvre, P., Rose, G. A., Gosine, R., Hale, R., Pearson, W. and Khan, R. 1999. Acoustic species identification in the Northwest Atlantic using digital image processing. Fisheries Research. In press.

Lilly, G. R. 1998. By-catches of capelin during spring and autumn bottom-trawl surveys in Divisions 2J3KL in 1997. DFO CSAS Res. Doc. 98/63: 79-113.

Miller, D. S. 1997. Results from an acoustic survey for capelin (*Mallotus villosus*) in NAFO divisions 3KL in the spring of 1996. DFO CSAS Res. Doc. 97/29: 84-90.

Rose, G. A. and Leggett, W.C. 1988. Hydroacoustic signal classification of fish schools by species. Canadian Journal of Fisheries and Aquatic Sciences 45: 597-604.

Rose, G. A. 1998. Acoustic target strength of capelin in Newfoundland waters. ICES Journal of Marine Science 55:

Shackell, N. L., Carscadden, J. E. and Miller, D. S. 1994. Diel vertical migration of capelin (*Mallotus villosus*) and its effect on acoustic estimates of density. ICES C.M. 1994/Mini:5 18pp.

Toresen, R., Gjosaeter, H. and de Barros, P. 1998. The acoustic method as used in the abundance estimation of capelin (*Mallotus villosus* Muller) and herring (*Clupea harengus* Linne) in the Barents Sea. Fisheries Research 34: 27-37.

Winters, G. H. 1969. Migrations of coastal capelin in Trinity Bay. Fisheries Research Board of Canada, St. John's Biological Station Circular 16: 10-11.

Table 1. Capelin target strength calculated from length-frequency data for surveys in Placentia Bay in 1998-99.

Survey	Mean σ (m^2)	Mean TS (dB)	Mean length (mm)
January 1998	7.458E-05	-52.27	110
March 1998	6.545E-05	-52.83	102
June 1998	9.846E-05	-51.06	125
January 1999	7.283E-05	-52.37	108

Table 2. Parameters and capelin biomass estimates for outer Placentia Bay (see text and Fig. 1 for region boundaries).

Survey	Transect block	No. of 100-m bins (n_A)	Min. capelin density	Max. capelin density	Mean capelin density	Variance capelin density	Mean capelin weight (g)	Transect area (m²)	Number of capelin	Capelin biomass (tons)
January 1998	all	2186	0	23.54	0.4922	2.392	5.03	4.64E+09	2.28E+09	11,500
	1	734	0	23.54	0.8224	5.496	5.03	2.17E+09	1.78E+09	8,960
	2	739	0	8.667	0.6080	1.294	5.03	1.25E+09	7.61E+08	3,830
	3	530	0	0.639	0.0198	0.0018	5.03	8.76E+08	1.74E+07	87
	4	183	0.0013	0.323	0.0687	0.0046	5.03	3.11E+08	2.14E+07	107
	sum								2.58E+09	13,000
March 1998	all	2020	0	33.95	0.1228	1.156	5.32	4.64E+09	5.69E+08	3,030
	1	728	0	0.618	0.0203	0.0041	5.32	2.17E+09	4.40E+07	234
	2	634	0	0.878	0.0325	0.0069	5.32	1.25E+09	4.07E+07	216
	3	440	0	0.566	0.0459	0.0054	5.32	8.76E+08	4.02E+07	214
	4	218	0	33.95	0.8826	10.06	5.32	3.11E+08	2.74E+08	1,460
	sum								3.99E+08	2,130
June 1998	all	4163	0	143.0	2.8194	50.22	10.34	4.64E+09	1.31E+10	135,000
	1	1003	0	69.51	1.0734	6.999	10.34	9.01E+08	9.67E+08	10,000
	2	777	0	24.31	2.0290	8.259	10.34	1.45E+09	2.94E+09	30,400
	3	617	0	74.41	3.5667	30.01	10.34	9.01E+08	3.21E+09	33,200
	4	503	0	143.0	3.1067	93.67	10.34	3.68E+08	1.14E+09	11,800
	5	553	0	96.73	4.9612	151.8	10.34	4.49E+08	2.23E+09	23,000
	6	370	0	31.12	4.5151	32.94	10.34	4.01E+08	1.81E+09	18,700
	7	340	0	94.71	2.6661	78.46	10.34	1.65E+08	4.40E+08	4,550
	sum								1.27E+10	132,000
January 1997	all	2329	0	0.417	0.0162	0.0008	4.84	4.64E+09	7.50E+07	363
	1	761	0	0.111	0.0080	0.0002	4.84	1.02E+09	8.20E+06	40
	2	562	0	0.102	0.0205	0.0002	4.84	1.41E+09	2.89E+07	140
	3	412	0	0.178	0.0176	0.0006	4.84	1.21E+09	2.13E+07	103
	4	274	0	0.393	0.0233	0.0032	4.84	6.31E+08	1.47E+07	71
	5	320	0	0.417	0.0201	0.0011	4.84	3.62E+08	7.28E+06	35
	sum								8.03E+07	389

Table 3. Parameters and capelin biomass estimates for inner Placentia Bay.

Survey	Transect block	No. of 100-m bins (n_A)	Min. capelin density	Max. capelin density	Mean capelin density	Variance capelin density	Mean capelin weight (g)	Transect area (m^2)	Number of capelin	Capelin biomass (tons)
January 1998	inner	1414	0	5.781	0.0133	0.0249	5.03	1.07E+09	1.43E+07	72
March 1998	inner	1469	0	7.999	0.0710	0.0768	5.32	1.07E+09	7.59E+07	404
January 1999	inner	1544	0	18.34	0.2313	1.492	4.84	1.07E+09	2.48E+08	1,200
	Paradise	688	0	31.57	4.5956	48.49	4.84	6.56E+07	3.01E+08	1,460

Figure Legends

Fig. 1. Expanding symbol plot showing capelin distribution in Placentia Bay during surveys in January, March and June 1998 and in January 1999. Acoustic data were averaged into 5-km segments for the purpose of display. '+' symbol indicates no capelin were detected in that segment. Circle sizes are proportional to $\log_{10}$(capelin density). The outer Bay region and transect blocks used for estimating biomass are indicated and numbered.

Fig. 2. Length frequency distributions of capelin sampled during acoustic surveys. The number of fish measured (n) is given. Capelin were measured to the nearest centimetre.

Fig. 3. Diel depth distribution of capelin observed during acoustic surveys. Relative position in the water column is a measure of the depth of peak capelin density standardised for water depth. A value of 1 indicates capelin were at the surface, while a value of 0 indicates capelin were close to the bottom. Hourly means and standard errors are shown as a function of Newfoundland Standard Time (GMT – 3.5h).

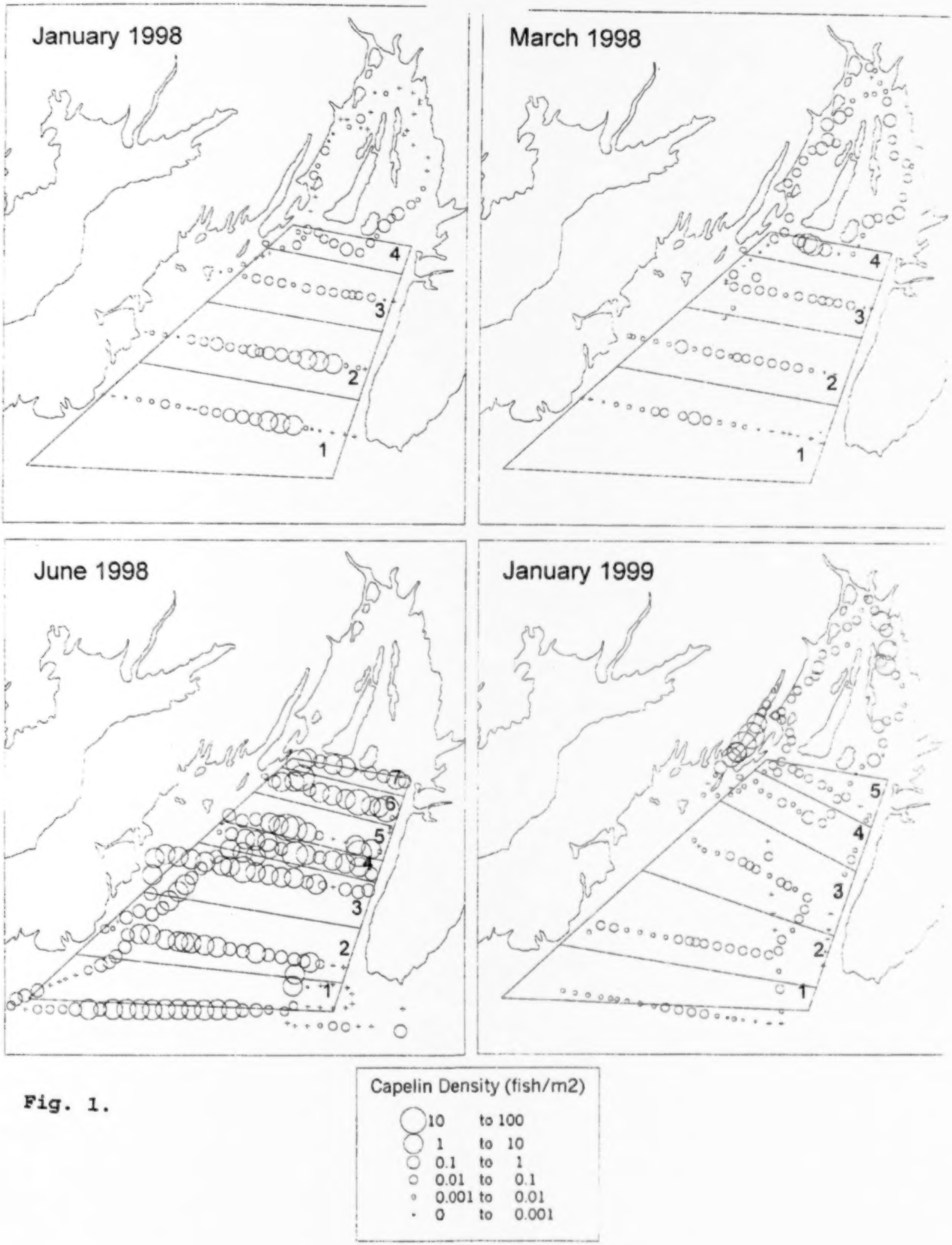
January 1998
1
2
3
4
March 1998
1
2
3
4
June 1998
1
2
3
4
5
6
7
January 1999
1
2
3
4
5
Capelin Density (fish/m2)
10 to 100
1 to 10
0.1 to 1
0.01 to 0.1
0.001 to 0.01
0 to 0.001

Fig. 1.

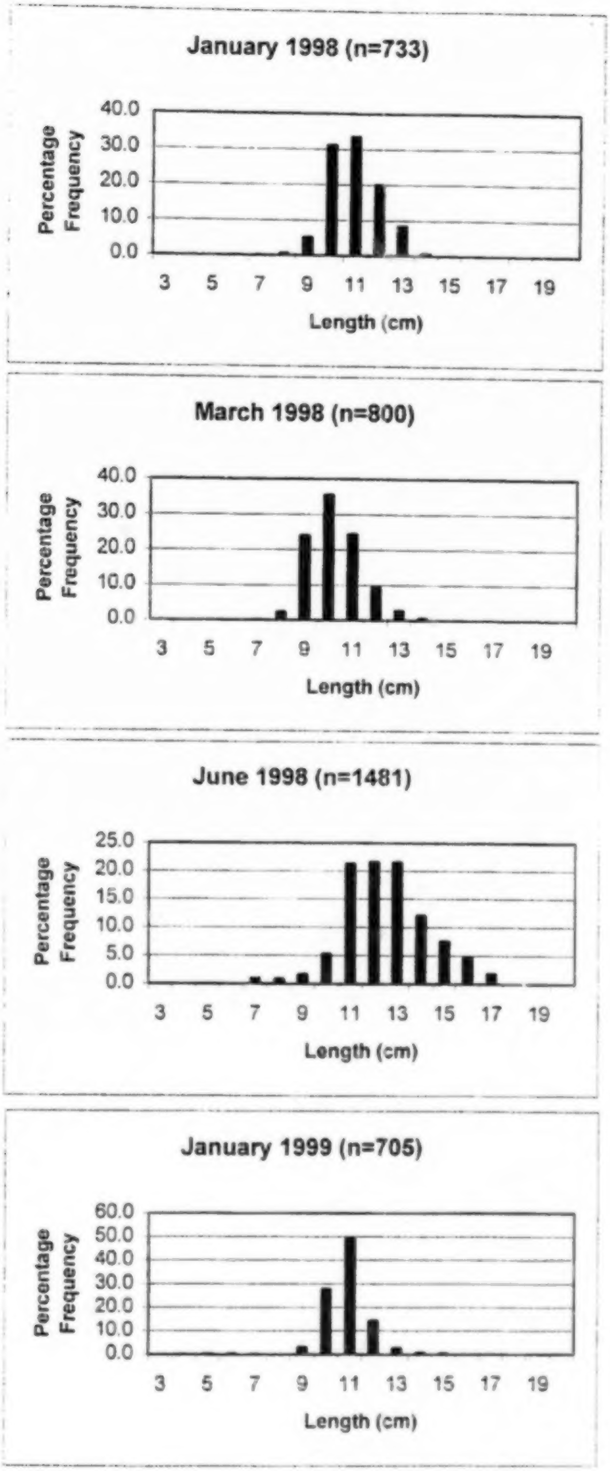
January 1998 (n=733)
Percentage Frequency
40.0
30.0
20.0
10.0
0.0
3
5
7
9
11
13
15
17
19
Length (cm)
March 1998 (n=800)
Percentage Frequency
40.0
30.0
20.0
10.0
0.0
3
5
7
9
11
13
15
17
19
Length (cm)
June 1998 (n=1481)
Percentage Frequency
25.0
20.0
15.0
10.0
5.0
0.0
3
5
7
9
11
13
15
17
19
Length (cm)
January 1999 (n=705)
Percentage Frequency
60.0
50.0
40.0
30.0
20.0
10.0
0.0
3
5
7
9
11
13
15
17
19
Length (cm)

Fig. 2.

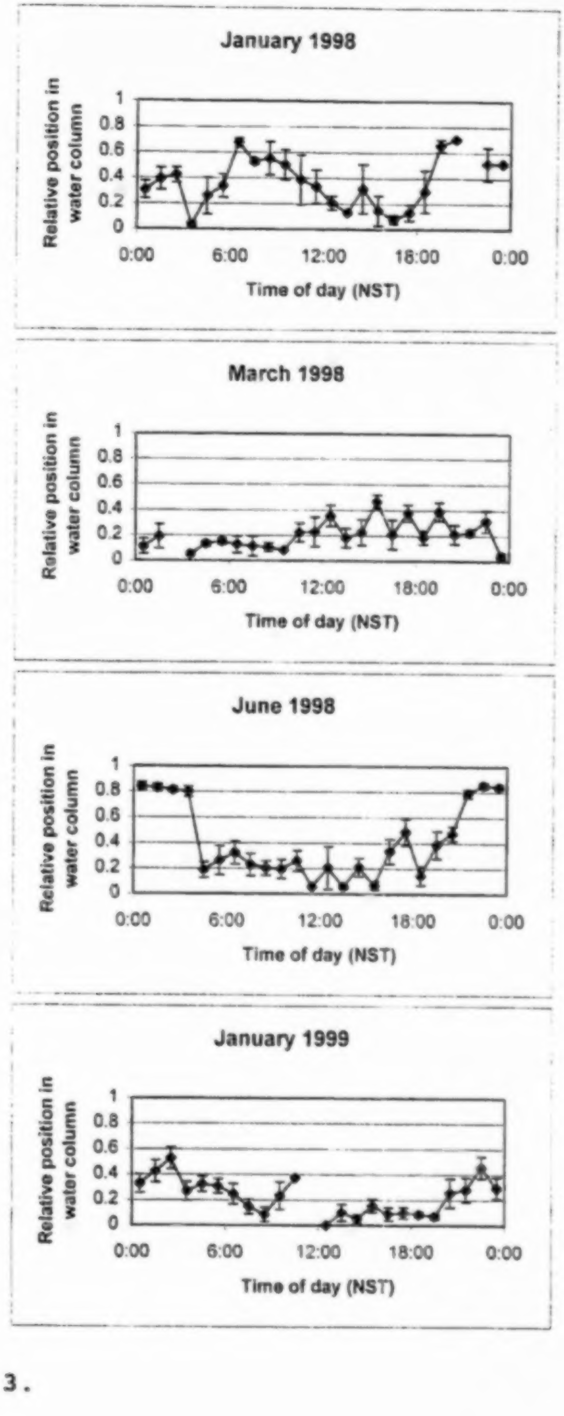
January 1998
March 1998
June 1998
January 1999
Relative position in water column
1
0.8
0.6
0.4
0.2
0
0:00
6:00
12:00
18:00
0:00
Time of day (NST)

Fig. 3.